BLUEPRINT READING

FAIRFIELD · KENISON · WAITE

BLUEPRINT READING

A PRACTICAL MANUAL OF INSTRUCTION IN BLUEPRINT READING THROUGH THE ANALYSIS OF TYPICAL PLATES WITH REFERENCE TO MECHANICAL DRAWING CONVENTIONS AND METHODS, THE LAWS OF PROJECTION, ETC.

BLUEPRINT READING

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MECHANICAL DRAWING

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ILLUSTRATED

AMERICAN TECHNICAL SOCIETY

CHICAGO

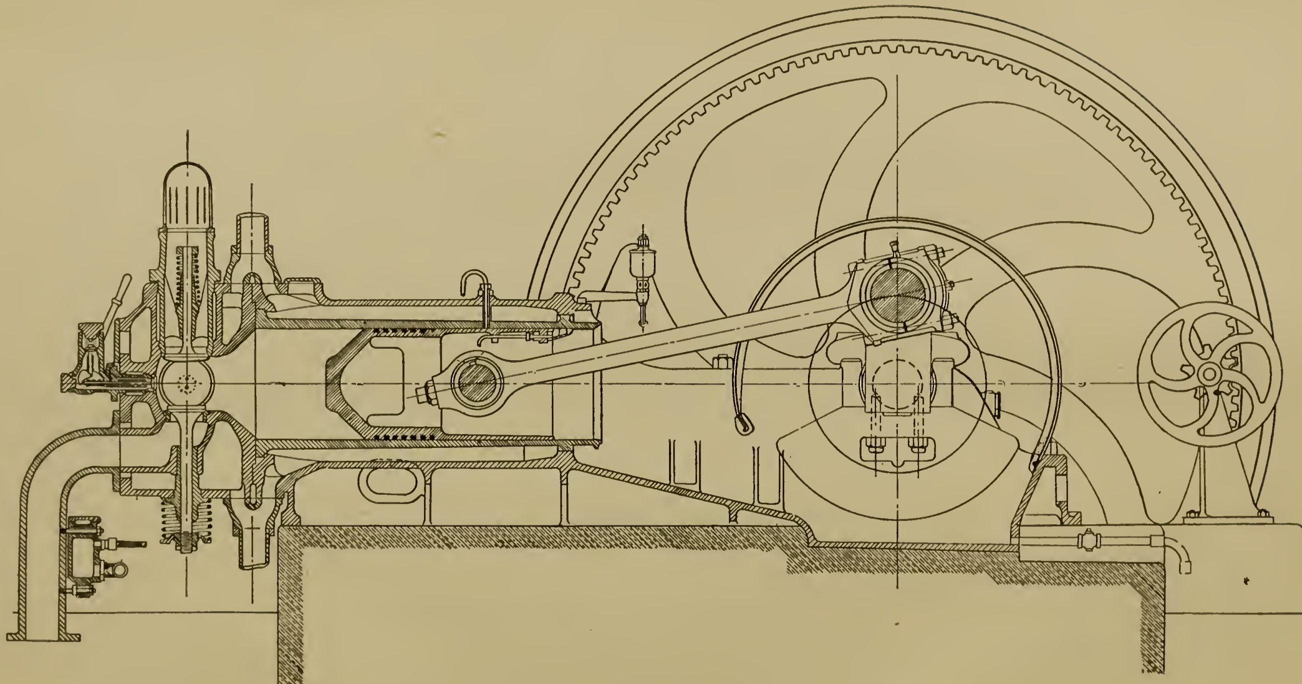
1919

INTRODUCTION

BLUEPRINTS are the language by which a designer expresses his thoughts to the fabricator. They may represent some complicated machine which will be made in fifty separate pieces and will go together like a jig puzzle; they may represent the specifications for a big bridge or roof truss which will guide the steel fabricator in the assembly of angles, channels, and eye-beams into a riveted unit of steel, just the right span and supporting power for the place it is intended to fill; they may consist of the elevation and plans of a house, showing foundation, framing, outside and inside finish, electric wiring, water and gas piping—in fact every detail necessary to make the building complete.

¶ These specifications were originally made by draftsmen, skilled in the art of mechanical drawing. These men had first to lay the foundation for the more advanced work by learning the kind of equipment necessary for drawings of various kinds, the use of the T-square, the triangle, the ruling pen, and all the other instruments which must be used from time to time. They had to train their eyes to visualize objects and measure distances and their hands to draw with precision lines of uniform width and accurate direction. They had to learn the rules of geometrical construction; the methods of representing plans and elevations of objects; and the principles of orthographic and isometric projection and profile work.

¶ It would be well if every workman were able to make good mechanical drawings, for with the ability to make them would come the ability to interpret them. But there are often many reasons why this is not possible, and it is with the idea of giving the requisite amount of drafting knowledge and practice in visualizing the finished product from plans, elevations, and sections that this little volume has been prepared. With a careful study of the lessons herein laid down will come the ability to "read" a blueprint like a book, to translate every shade of meaning intended by the designer, and thus to be able to carry out the job in an accurate, efficient, and workman-like manner.



SECTIONAL ELEVATION OF NEW CROSSLEY OIL ENGINE
Courtesy of Crossley Brothers, Manchester, England

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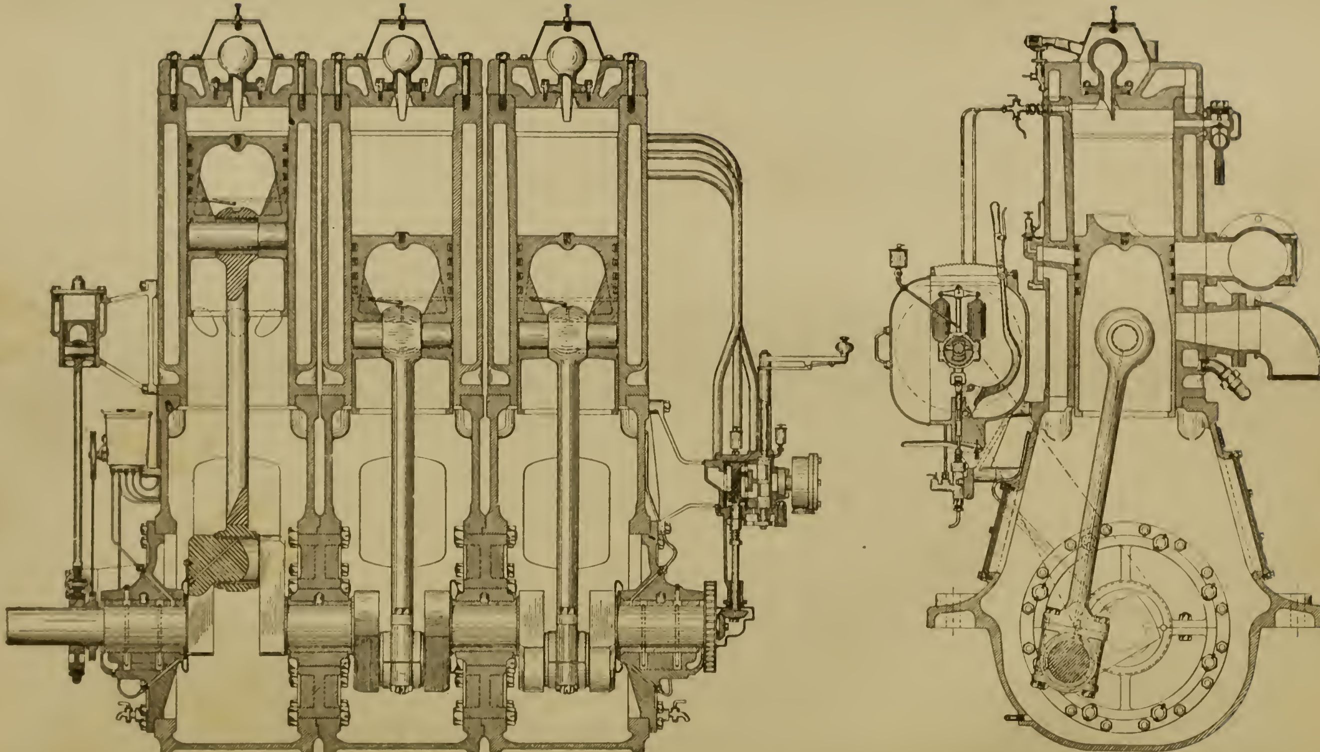

LONGITUDINAL AND TRANSVERSE SECTIONS OF MIETZ AND WEISS OIL ENGINE

Courtesy of August Mietz, New York City

BLUEPRINT READING

INTRODUCTION

Definition of Blueprint. A blueprint as used by engineers and by workmen in the various industries is a reproduction of what is known as a *working drawing.* A working drawing, as made by the draftsman, shows by means of lines what the piece, machine, or construction is, gives the necessary working dimensions and whatever other data the workman needs to know in order to build the piece or the structure; in other words, it is the drawing by which the workman does his work and to which he looks for his information when building the structure or machining the part. However, it is essential that the working drawing itself be preserved for reference in the drafting room, and therefore a blueprint is made from the working drawing and this is what the workman uses at his machine or in the field. The lines, numerals, and letters on the original working drawing are black on a white background but these appear on the blueprint as white lines on a blue background; hence the name *blueprint.*

Process of Making Blueprints. Blueprints are contact prints; that is, the blueprint paper and the working drawing are in contact with each other while exposed to the light. Blueprint paper is a strong rather tough white paper coated with a solution which is sensitive to sunlight and turns blue when exposed to sunlight and then washed in clean water. Those firms which use large numbers of blueprints often coat their own paper. Most firms, however, buy it in the open market already coated with the prepared sensitive solution. In making a blueprint, the working drawing is laid face down on a sheet of clear glass and the blueprint paper, cut to a size slightly larger than that of the drawing, is laid on the drawing with the colored, or sensitive, side next to the drawing and by means of a clamping frame is brought and held firmly in close contact with the drawing. The holding frame is then tipped and held in a position to allow the sun or other strong light to shine squarely through the glass. The light thus

passes through those parts of the drawing on which there is no ink and effects a chemical change in the light-sensitive blue coating. The light does not shine, or pass, through the inked lines of the drawing, the lettering, or the numerals. After a short exposure to a strong light the clamps are removed and the blueprint paper is taken out of the frame and thoroughly washed in clean water. The parts upon which the strong light shone turn a rich blue color; those parts which came under the inked lines were not affected by the light rays and wash up a clean sharp white.

Importance of Blueprints. The blueprint from a properly made working drawing should contain *all* the information needed by the workman in his work and he should never ask for information until he is positive that it is not on his blueprint. It is well also for him to understand that his blueprint is an exact reproduction of a drawing on file in the drafting room and that, if he implicitly follows instructions and dimensions as given in his blueprint, he is protected in any argument which occurs over his work; in other words, if his work checks up with the blueprint he has worked from, any errors found in results are squarely up to the draftsman.

What Blueprints Should Show. A blueprint is in a sense a picture of the piece, machine, or structure which is to be made or built. This picture is made up of views; for example, front view, top view, end view, etc. (See "Mechanical Drawing," Part III, pages 73–79.) These views are made up of lines which would show clearly to the eye if the part, machine, or structure were viewed from the several positions noted; for example, a front view consists of those lines which would be clearly seen if the observer were viewing the part or machine from the front. The blueprint should also contain all the essential dimensions and indicate clearly from what surfaces they are to be taken In most cases, this is done by using a distinct arrowhead with the point resting against the line which represents the surface or the outline from which the measurement starts or from such a working line *extended;* that is, the line which represents a surface edge is lengthened to make it convenient for placing the arrowhead. Another arrowhead is placed against the line representing the surface where the measurement stops, and the two arrowheads are connected by a line called a dimension line and the given dimension is placed either in this

line or directly over it. Fig. 1 shows this. The blueprint will probably also contain lettered directions; some surfaces are to be ground, and the word "grind" may be lettered on those surfaces, others are to be polished, and on those the word "polish" may be placed.

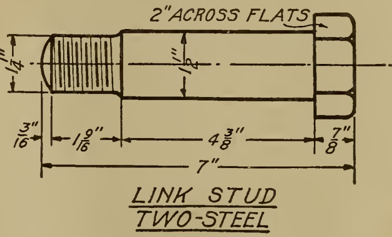

Fig. 1. Detail Drawing of Link Stud

Reading Blueprints. To be able to read a blueprint is as essential to a workman's success as to be able to read printed matter. To read blueprints readily, he must know some of the principles of making drawings. These are explained to a considerable length and with close attention to detail in "Mechanical Drawing," Parts I, II, and III, and these books should be read most carefully. This is somewhat equivalent to learning the alphabet in learning to read printed text. The workman should first understand that a blueprint is a record of instructions given him to read. Second, he should realize that the language used by the draftsman in making his drawing is largely a language of lines and that, unless he knows how to read lines, the instructions recorded on the blueprint are essentially in a foreign language. (Read carefully and memorize page 41, "Mechanical Drawing," Part II.) To read a blueprint, the first thing is to study the several views until one has a good mental picture of what he is to construct. As the blueprint is a flat surface, it is necessary for the workman to use his imagination to make the lines and views lift up from the paper. When a clear-cut mental picture has been formed, the dimensions should be studied until understood. Next all the lettered text should be read and considered. Carelessness in any one of these three respects is not to be excused.

GENERAL DIRECTIONS FOR READING BLUEPRINTS

Method of Obtaining Views. As already noted in the "Introduction," a blueprint represents the information which the draftsman is seeking to convey to the workman. It becomes necessary then for the workman to think somewhat as the draftsman thinks. Plate I, page 14, consists of three separate outlines, or diagrams.

These diagrams are known as views and are obtained by projecting the outlines of the piece point by point onto an assumed plane. (Read carefully the matter under "View" and "Projection" in "Mechanical Drawing," Part III, page 73, and study Fig. 95.) In the case in hand, the paper on which the drawing is made is the plane, and as the blueprint is an exact reproduction, line for line and point for point of the original, it also can be said to be the projecting plane. As an aid in understanding what the draftsman did when he made these *views* and why they are placed on the paper as they are, let the reader imagine that with a sheet of paper he has made a *box* having all the corners and all the sides square with each other. Assume that the paper box is transparent as glass is transparent and that a piece of work might be hung inside the box centered with the sides and corners. Let us now in imagination hang various objects one at a time in this paper box centered squarely with its transparent sides through which they may readily be viewed. (Carefully study Fig. 102, "Mechanical Drawing," Part III, page 79.) If the first object selected is a perfect cube, for example, an ordinary playing dice, then, viewing this from every side of the box, it is at once evident that all the views are the same in outline. If the outline dice is drawn, with a pencil, on each side of the box, as seen through that side, we will have six outlines all of the same size and shape. If an ordinary playing domino is substituted for the dice, the views when looking into the top and the bottom of the box will be alike in outline. Those seen when looking into the right and the left ends will also be alike, as will the views seen when looking through the back and the front sides of the box. If the pencil is used as before, six outlines are shown, but instead of their being each like the other, there are three pairs of views, each pair distinctly different from the others. If these penciled views are labeled top, bottom, front, back, right end, and left end, and the paper box is cut along its corners and the paper then tacked flat on a board, we have a drawing of the piece giving six views labeled top, bottom, etc.

Instead of doing all this box work, the draftsman first trains his hands as shown in "Mechanical Drawing," Part I, pages 22–29, to use in a neat and skillful manner the various tools shown and described in pages 1–17. He also trains his hands to produce and

his mind to remember the various outlines shown in "Mechanical Drawing," Part II, pages 41–54. In addition, he must learn to imagine what he is going to make a drawing of, or, as it is termed, see the thing in space, which means form a reasonably complete *mind* picture of the piece he is to draw. In "Mechanical Drawing," Part III, pages 80–86, it is shown by what methods the draftsman avoids having to use a box with transparent sides when making a drawing; by using the tools shown in Part I, pages 1–17, in a certain conventional manner, he gets all the views he wishes on a sheet of paper tacked flat on a board.

Number of Views Needed. It will be recalled that in viewing the domino centered in the box, while we had six separate views, certain views duplicated and three views were sufficient to show clearly the outline of the piece. When drawn, some machine parts need several different views; others need only a single view. In Plate I the draftsman considered that he could get all the information the job needed on three views, namely, a front view a top view, and an end view.

Interrelation of Views. In reading Plate I and other blueprints, it will be observed that the top view and the front view center, line for line and point for point, on the same *vertical* center line, also that the front view and the end view center, line for line and point for point, on the same *horizontal* center line. Plate I, "Mechanical Drawing," Part I, page 26, shows a series of horizontal lines and a series of vertical lines, and it is explained in Part III, pages 73–86, how the vertical and horizontal reference lines work out in the drafting room. In some of the plates, it has been found necessary to readjust the different views to accommodate them to the small size plate, in violation of the rules of *third angle projection.* The student should make allowance for these discrepancies.

Meaning of Projection. To understand thoroughly what the term "projection" means, it is well to study the action of light as we view an object. Take as an example a man walking along the street. Our view of that man is made possible by the fact that light is *reflected* from his body into our eyes. This is true of all objects which we view with our eyes and we say that we *see* the man or the object. In other words, the light which is reflected, or thrown back, from the man or from the object into our eyes

gives us a view of the man or the object. If the man or the object faces toward us, we get a front view, if away from us, a rear view. While the object itself is not a source of light, it is so treated in viewing it and the light is said to be projected from the object viewed. When a view drawing is made, it is often known as a *projection*.

Projection of House. In "Mechanical Drawing," Part III, page 118, Fig. 160, is shown an isometric projection of the ordinary house. As an example of *ordinary* projection, suppose we select such a house and view it from its several sides, at a distance of not less than 100 feet from the several sides. Taking the front end first, the viewer will note that it appears as a flat wall having a rectangular outline with its top line in the shape of an inverted V. A side view gives a bottom line where the house rests on the foundation, two vertical, or upright, lines at each end of the side, a horizontal, or level, line to show the eaves, and a second horizontal line above this to represent the ridgepole. If these two views have been penciled out on a sheet of paper to some exact size, they will show what the *outline* of the house is. We can also show on these views the several doors, windows, etc., as we see them when viewing the front end and when viewing one side of the house, and if the rear end and the opposite side have the same doors, windows, etc., in exactly the same positions, the workman would be able from these two views to construct walls which would be as desired. If, however, the rear end had the doors or the windows placed differently from those on the front end or if they were not of the same size even though placed in the same manner, the workman would need a rear view to show him this fact. The same thing would hold true in respect to the sides of the house. Also, if the roof itself were broken up by windows, a top view showing their size and layout would be necessary for the workman. For convenience in making and reading the drawing, the several views are universally arranged for shop use exactly opposite the surfaces which they represent, as noted in the use of the box with transparent sides.

Lines. *Working Lines.* A study of the views in the several blueprints in this book shows at once that each view is made up of straight lines and curved lines. The straight lines, or right lines (as they are often termed by draftsmen), are used to repre-

sent the edges of plane surfaces. How such lines are drawn and the tools used for drawing them are shown in "Mechanical Drawing," Part I, pages 22–25. In the example just used, two upright straight lines a certain distance apart would be used to show the corners of the house. A circle line may show the edges of a cylinder or a hole in any surface, for example, a bolt hole or, in a house, a circular window. By using a combination of straight lines and part of a circle, the rounded end of a straight-sided bolt, for example, can be shown. Where the edges are neither straight lines nor parts of a circle, they are drawn with a special tool having an irregularly curved edge, which can be fitted to the desired line shape. (See Figs. 32 and 33, "Mechanical Drawing," Part I, pages 16 and 17.) A view, then, may consist entirely of straight lines, entirely of curved lines or of circles, or of a combination of all these. It must in any case be clearly noted that any *working* line, straight or curved, is used to show where a surface on the work changes its direction, in other words, to show the *edge of a surface.* If the object viewed is a solid piece, for example, a bolt, all the working lines in the several views are solid and continuous straight or curved lines. If the work has holes through it or has hollow places hidden inside it, the lines which show the hidden edges are drawn as dots and the line is termed a dotted line. (See Fig. 110, "Mechanical Drawing," Part III, page 84.) In studying a blueprint then, it will be understood that the dotted lines in a view represent surfaces and edges which are hidden from the viewer's sight when the object is viewed from the side shown. In the case of the bolt, Fig. 1, a view of the head end would show the body of the bolt as a dotted circle. In a blueprint of the house, the wall timbers, partitions, etc., which are not seen from the outside, would be shown as dotted lines.

Dimension Lines. While the house outlines as they now stand give a general idea of how its exterior would look, they do not show its size or the sizes of the several doors, windows, trim, etc. To give this information, use is made of *dimension* lines drawn between points on the lines which make up the several views. To indicate the place where the measurement is to start and the point where it must stop, each end of a dimension line has a neat arrowhead, the point of which just touches the line at which the

measurement starts or stops. Somewhere in the length of a dimension line are placed the numerals which give the exact measurement of the work as indicated by the arrow points. Dimension lines usually show on the blueprint much thinner than the lines which make up the views. This fact and the fact that at their ends are prominently placed neat arrowheads render it easy to avoid confusing them with the working lines of the blueprint.

In case a dimension line cannot readily be placed on the view, the working lines may be lengthened, or extended, a short distance from the view and the dimension line can then be drawn between the extended lines with the points of the arrowheads resting exactly against the extended lines. The end of an *extension* line, as it is called, should never quite touch the working line which it extends.

Section Lines. In addition to the working lines and the dimension lines on the blueprint views, the workman will, in some cases, find a series of parallel lines drawn closely together at an angle to the working lines of the view. These are known as *section* lines and are used by the draftsman to tell the workman that the part of the view covered by such lines is as if the work had been cut through and a portion removed. (Plate I, Fig. 3, "Mechanical Drawing," Part I, page 26, shows an example of section lines.) Sections open up the interior of an object or a combination of working parts, for example, the headstock of a lathe, and give a clear view of the inside. To use a homely illustration, the draftsman seeks the same effect as the grocer does when he cuts a melon in halves for the customer's inspection. A view so drawn is said to be *sectioned;* hence the term section lines. In the case of the lathe headstock, some of its parts may be of cast iron, some of bronze, some of steel, etc. To show which parts are of cast iron, of steel, or of bronze, the draftsman makes use of various arrangements of section lines, each arrangement showing a different material. In Plate III, "Mechanical Drawing," Part I, page 35, are shown and named the common arrangements of lines to show sections of different materials, viz, metals, wood, brick, concrete, etc. The workman should study those common to his work.

Drawing Sheet Sizes. In "Mechanical Drawing," Part I, page 2, is given a list of sizes of drawing sheets. While different shops may use different sizes for their blueprints, as a rule each

shop has some regular system of sizes. A common system for machine shops makes the largest regular sheet 24″×36″ and lists it size **A**. Such a sheet will fold and cut to give two **B** sheets 18″×24″. Continuing the folding and cutting gives a **C** size 12″×18″; a **D** size 9″×12″; and an **E** size 6″×9″. A machine shop blueprint is usually trimmed to one of these sizes.

Methods of Showing Large Work. *Reducing Scale of Drawing.* Several methods are used to make it possible to show a view of large work on a small sheet of paper. The view is often made a reduced size, which is usually spoken of as making it to a *reduced scale.* The term "scale" in such a case means that the length of the working lines in the blueprint views has a definite proportion to that of the actual lines of the work itself; for example, if the circles which represented the rim of a 24-inch pulley were drawn in a view as 12-inch circles, the view would be one-half size, or to one-half scale. If the circles were made 6 inches in diameter, the view would be to one-quarter scale. While in these cases the dimension lines would be, respectively, 12 inches or 6 inches in length from arrow point to arrow point, the dimension figures would read the exact size, 24 inches. For the reason that a blueprint view on a reduced scale does not give the average workman a good *size* picture of the work, it is customary to have the views show the work to exact, or full, size whenever it is practicable to do so. Such a view is known as a full-size view, or a full-scale view. The common machine shop *view scales* are one-eighth, one-quarter, one-half, three-quarters, and full size. Another way of expressing view scales is in inches to the foot; for example, a one-half scale is 6 inches to 1 foot and a full scale is 12 inches to 1 foot.

Showing Parts of Work. Another way of getting a view of a comparatively large piece of work into a small space on a blueprint is to show only a part of the work in the view. In the case of the pulley just mentioned, if the blueprint view showed one-quarter or one-half of the entire pulley, the average workman would be able to get all the directions necessary from the view to complete the work.

Breaking the Piece. Yet another way by which the space utilized to represent a piece of work in blueprint views can be lessened is what is known as breaking the piece. To illustrate, use is

made of the front view of a long bolt or shaft of relatively small diameter. If such a piece were shown full scale, its working length lines might reach the entire length of the blueprint or even farther. If the body of the bolt or shaft is of uniform size and shape, it is sufficient to show a portion of the body near the head and a portion near the threaded, or opposite, end, and the portions shown may be brought close up to each other and thus little space used for the view. When analyzing the several blueprints reproduced in the following pages, the ways in which space is utilized in representing the parts of the work will be noted.

Shade Lines. It must be admitted that the average blueprint view of a piece of work is a rather flat and dead thing and that some imagination on the part of the workman is needed to give it life and to make it lift up from the paper and really have form and substance. Fortunately for the machine shop workman who is just learning to read blueprints, much of his work comes to him roughly in the form in which he is to finish it. This is especially so when he is finishing ordinary castings. There are several methods used at times to give the blueprint views more "life". One much used method is to make certain of the working lines of increased thickness to represent a shaded portion. These heavier working lines are known as *shade* lines and aid somewhat in making the view stand, or lift, up from the paper. Such shade lines are used to a lesser extent now than formerly, as the workman is supposed to use his imagination when reading blueprint views.

Line Shading. The term *shade lines* should never be confused with the term *line shading* which refers to a decidedly different use of lines. Line shading as commonly used consists of a series of lines placed on the view within its working lines and arranged in such a manner as to give a picture effect to the view. In "Mechanical Drawing," Part III, pages 126 and 127, are shown a variety of objects which have been line shaded. Comparison of these illustrations with Figs. 78, 81, and 84, "Mechanical Drawing," Part II, pages 49 and 50, clearly shows what line shading does to liven up a view. As is the case with shade lines, line shading is used less in machine shop drawings than it formerly was.

Finish Lines. Another line used in blueprint views is sometimes termed a *finish* line. Such a line is usually broken up into

dashes and dots and is then known as a *dashed* line. It is placed on the view close to a working line to indicate that the surface represented by the working line is to be finished. Dashed lines are now little used for this purpose because of the chance of their being confused with dotted lines used to represent hidden surfaces and edges, and other methods of indicating finished surfaces are popular. Brown & Sharpe practice is to use a red pencil to draw a full red line on the blueprint views close beside all working lines which represent finished surfaces. A common method of indicating finish is to place a letter *f* across all working lines which represent finished surfaces.

Symbols Used. There are a number of words which often appear on blueprint views, each conveying certain information, and the workman must be familiar with the more commonly used ones to read his blueprint readily. The word "ream" near a hole shown in the view means that the hole is to be finished by reaming it; the word "tap", if so placed, indicates that the hole is to be tapped. The terms which the workman is most likely to find on his blueprint views are ream, tap, grind, polish, scrape, frost, taper, crown, and drill. He will also often note the letters *F.A.O.* near certain views; when so found, they denote that the piece of work is to be finished all over and the letter *f* is left off the working lines. It is also common machine shop practice to place on the blueprint the name of the piece of work, the number wanted, and the material to be used, all neatly lettered. The several materials used in the construction of machinery are usually indicated by their initials, for example, *M.S.* for machinery steel. To read blueprints easily and accurately, the workman should learn the symbols used, the more common of which are given and defined in the following tabulation:

F.A.O.	finished all over	C.I.	cast iron
f.	finished surface	S.C.	steel casting
RAD.	radius	Bz.	bronze
DIAM.	diameter	C.R.S.	cold rolled steel
R.H.	right hand	T.S.	tool steel
L.H.	left hand	O.H.S.	open-hearth steel
P.R.	piston rod	W.I.	wrought iron
P. Tap.	pipe tap	M.S.	machinery steel
CTRS.	centers		

Special notes neatly lettered are often placed on the blueprint and these notes should always be read carefully. In "Mechanical Drawing," Part I, pages 17–21, and Part III, pages 128–134, are shown examples of lettering. Each and every dimension line should have in clear distinct figures, either on the line or in a break in the line, the exact dimension which the dimension line represents. Dimension figures should be clear, distinct, and easily found and read. (Study Plate I, Fig. 4, "Mechanical Drawing," Part I, page 26.) Certain working variations in dimensions are allowable in all work. These are termed *tolerances* and should be given on the blueprint. They are usually preceded by the sign ± and are placed near or follow the given dimension. If the tolerances are not to be found, the workman must learn what the practice of the shop is in regard to this point.

Conventions Used. Certain conventions, as they are called, are often to be found on blueprints. Take screw threads as an example; they are seldom shown on a blueprint as actual threads but are *indicated* by an arrangment of parallel lines across the surface meant to be threaded, Fig. 1, page 3, and a note is usually lettered on or near the threaded surface giving the number of threads per inch and the form of the threads. Gear teeth are seldom shown on a blueprint; a lettered note is used instead to state the number of teeth in the gear and whether they are involute, cycloidal, or otherwise.

Intersections and Irregular Surfaces. While, in most cases, the workman can get the needed information from a sufficient number of views of the ordinary method of projection, this is not always true where two surfaces meet at an angle, especially if they meet or intersect at other than a right angle. As an example of such a case, take the spout of an ordinary tin coffee pot where it joins the body of the pot. In uniting the two, it is necessary to know just what the shape of the hole should be and its size; also, in making up the pot body and the spout body, each of which is usually tapered, it is necessary to know the exact shapes and sizes to which the sheet tin must be cut. All sheet-metal work is full of such problems, as well as work in leather, for example, shoe tops, bags, etc. To obtain the desired forms of the holes and the body of a sheet-metal object, it is in effect cut open and flattened

out as if it were a sheet of paper. The methods by which such problems are solved are very clearly shown in "Mechanical Drawing," Part III, under the headings "Intersections," pages 98–106, and "Development of Surfaces," pages 106–113. While the workman's blueprint should show the already developed surface, or pattern, he will better understand his job if he knows how such a pattern is made.

Single Picture Views. The practice in some shops is to furnish the workman with a small blueprint which has a single view of the piece he is to work on. These sketches can be made by the use of the regular draftsman's tools or, given sufficient artist's skill, may be made free hand. The excellent examples of such sketches given in Plates XXIX, XXX, and XXXI were, in the original, entirely free hand. Where one view is sufficient to show an object in its true shape, it must show the object tipped and turned into such a position as to give a picture view. The sketch artist views the object from a variety of angles, finally decides which view best shows the piece, and makes that the blueprint view for the workman. In "Mechanical Drawing," Part III, pages 113–125, the methods used to obtain these single picture views are described and illustrated.

Importance of Careful Study. The careful reader of the preceding text must now be impressed with the need of *knowing* things. The way to know a thing is to study it, just as a child studies his book when learning to read. The child first learns the simpler words, how they look, what letters of the alphabet are used in spelling them, how the words are pronounced, etc. Anyone who is willing to study this text and "Mechanical Drawing," Parts I, II, and III can learn how to read ordinary blueprints readily. To assist the reader of this text in doing this, a variety of simple blueprints have been selected for analysis. Although they by no means cover all classes of work, nevertheless, they have been selected from a large number as being the more typical of their kind. Carefully study each blueprint as well as the text, for, in the first place, you will become acquainted with good practice as carried out by several well-known firms and, in the second place, you will, by this thorough analysis, train yourself to see in any blueprint everything that was intended to be brought out.

ANALYSIS OF TYPICAL BLUEPRINTS

PLATE I

SADDLE NUT

It is evident that Plate I shows three views of a saddle nut. Before starting to read the views, the workman should read the lettered data at the top of the blueprint. From this he gets the name of the piece he is to make, "saddle nut," the number required, "one, on a single machine," the name of the machine to which the piece belongs, "5-foot boring mill," and the piece number, "14049." He next reads the lettered data at the lower edge of the blueprint and learns what material he has to work on, in this case, bronze. If this plan has been followed out, the workman now knows that he is to make a certain number of bronze saddle nuts, each of which is a part of a 5-foot boring mill.

The several views are a front view, a right end view, and a bottom view. The front view shows the piece as it would look when set on its flat base on the bench, with its long side toward the viewer. The right end view shows the piece as it would appear if set on the bench as before, but so placed that the right end would face the viewer as he stood at the bench. The remaining view shows the bottom, or base, of the piece as it would appear if the workman picked the piece up from its first position on the bench, held it above his head, and looked up at its bottom side. As both ends of the saddle nut are alike, no left end view is necessary; and as nothing is to be done to its upper, or top, surface or to its rear side, neither a top nor a rear view is necessary.

The dotted lines through the front and the bottom views show that there is a hole through the length of the work and the right end view shows that the hole is circular in shape. As the dotted lines through the front and the bottom are double lines exactly centered with the center lines of these two views and as the right end view shows a full-line circle and a dotted-line circle, something more than these lines are needed to tell us just what this hole is. Between the front view and the right end view are certain notes nicely lettered. They state that the hole has a left-hand square thread, four threads to the inch through its length,

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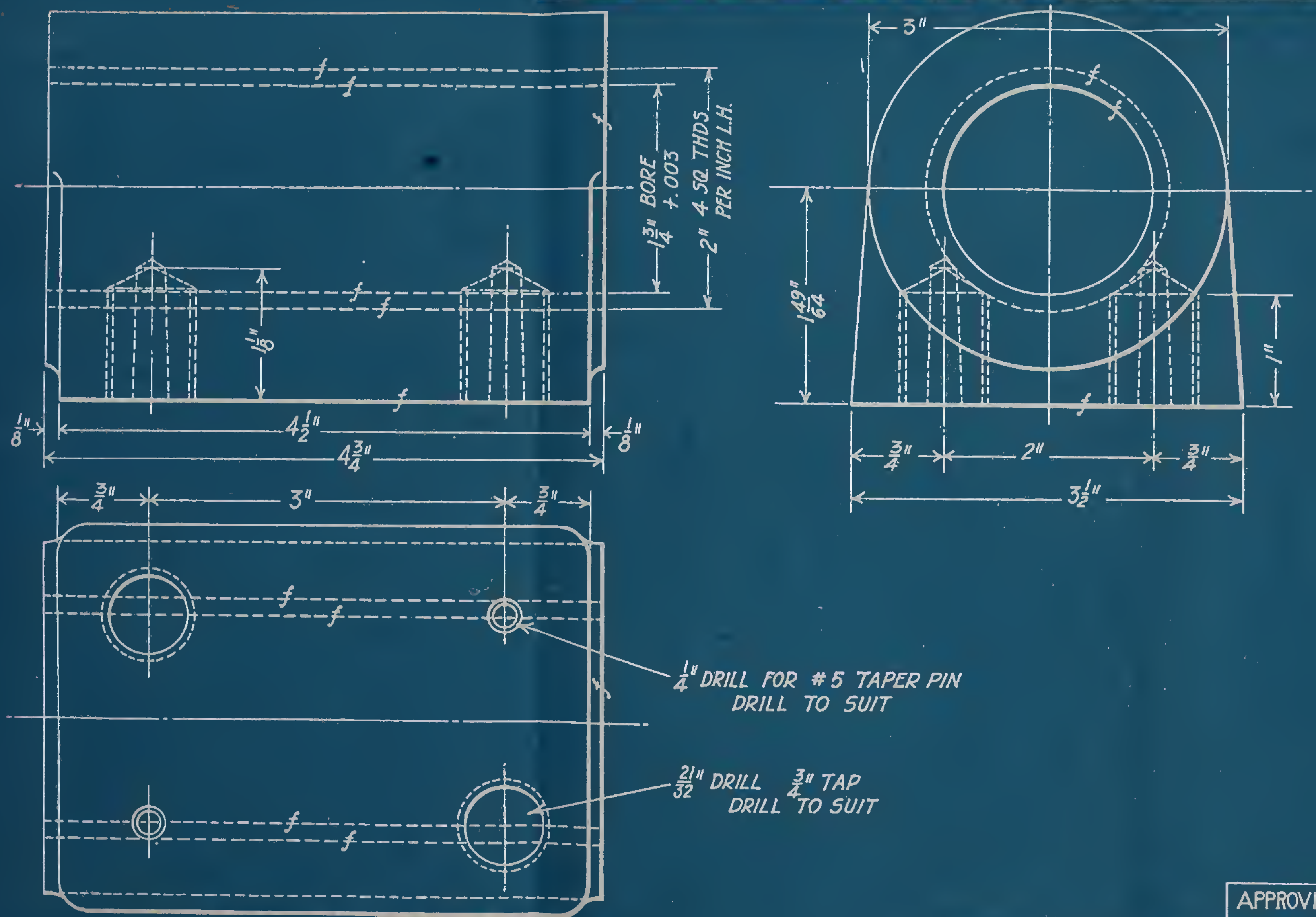
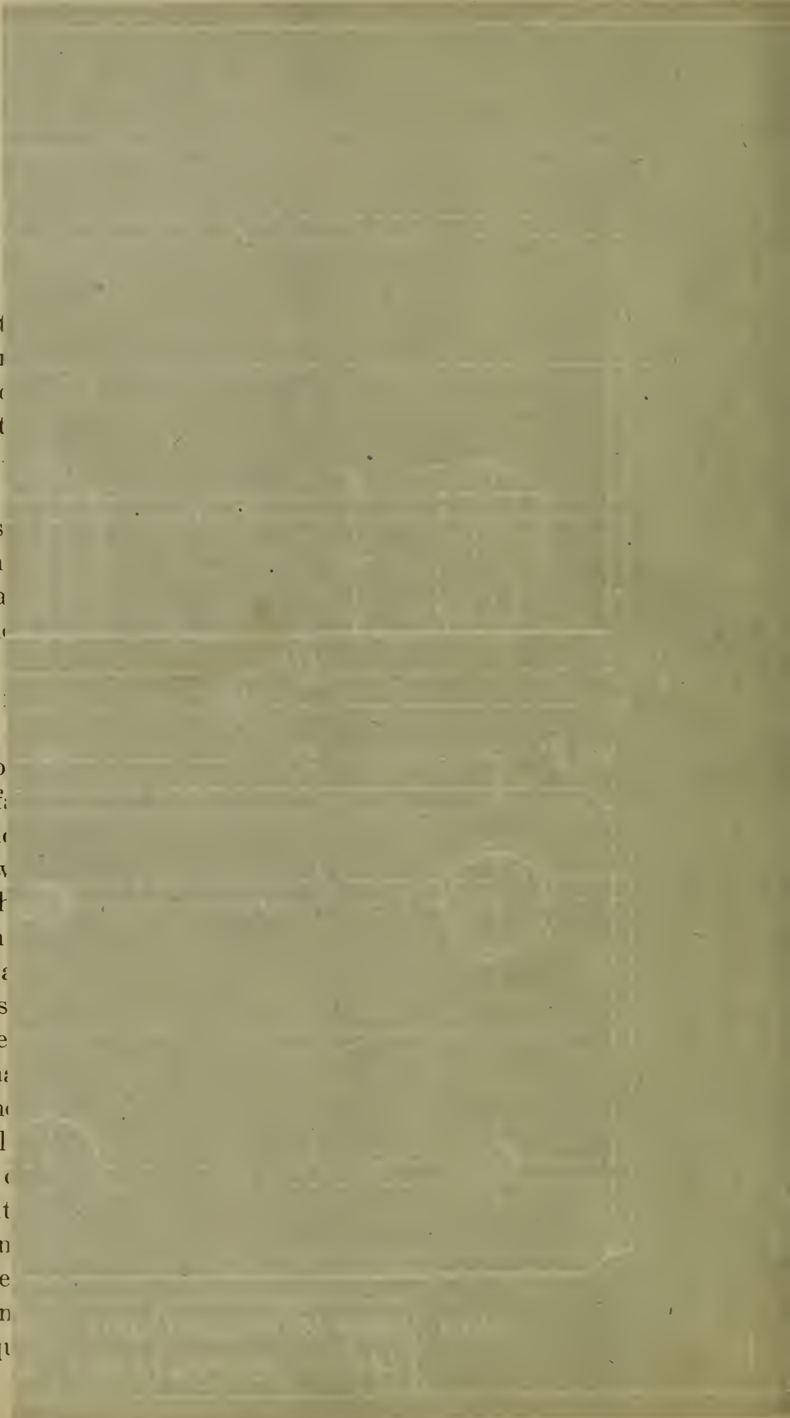
NAME OF PIECE	AMT. REQ.	NAME OF MACHINE	PIECE NO.
SADDLE NUT R.H. HEAD	1	5 FT BORING MILL	14049



APPROVED BY

14019

GROUP NO.	TRACED BY	DATE	CHECKED		MATERIAL	USE PATT. NO.	SIZE	LENGTH	PIECE NO.
14011	RGillham	4.17.17.	F.a	THE CINCINNATI PLANER CO.	BRONZE				14049



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make everything clear as to what the hole is, and explain the name "nut" given to the piece in the title.

Near the base of the front and the right end views are certain other dotted lines which, of course, represent hidden surfaces or holes. When we look at the bottom view, it is easily seen that these are round holes. By reading the notes placed at the right of this view and by following the arrows, we learn that two of these holes are to be made to fit a No. 5 taper pin and that the two larger ones are to be drilled and tapped for a $\frac{3}{4}$-inch screw. This view also shows that there is a screw hole and a pin hole in each end of the piece and that the screw and the pin holes are placed in corners diagonally across from each other. It can also be seen by reference to the several views that the screw holes and the pin holes are placed on the same center lines. If the workman is used to general machine construction, he will know that the screw holes are for the bolts which are to hold the saddle nut to the saddle and that the pin holes are for the taper pins which locate and hold the nut to an exact position. The bottom view shows by dimension lines placed just above the view that the holes are to be placed 3 inches from each other along the length of the piece and $\frac{3}{4}$ inch in from the edges of the base. The end view shows by dimension lines placed just below the view that along the width of the piece the holes are 2 inches apart and $\frac{3}{4}$ inch in from the sides. The workman should understand that when the dimension lines are shown in this manner, the *center-to-center* distance is the more important one. In this case, the 2-inch and the 3-inch dimensions are of more importance that the $\frac{3}{4}$-inch dimensions, these latter being probably given to inform the workman that the holes must be symmetrical with the base of the nut.

Attention is called to the placing of the dimension lines between or at the side of the views and to the fact that the arrow points touch extension lines drawn to nearly touch the surface lines. Dimension lines placed between the front view and the bottom view show that the saddle nut is $4\frac{3}{4}$ inches long over all and that the over-all length of the base is $4\frac{1}{2}$ inches. Dimension lines placed just below the right end view show that the base of the nut is $3\frac{1}{2}$ inches wide over all. A dimension line placed just above the end view shows that the rounded part of the

nut is 3 inches. While reading the over-all dimensions, for example, the $4\frac{3}{4}$-inch, the $3\frac{1}{2}$-inch, and the 3-inch dimensions, the workman should at the same time see whether or not his castings measure up fairly close to these dimensions with finish allowances.

Attention is called to the fact that all the dimensions are given either in whole numbers or in whole numbers and common fractions, with the exception of the dimension for the bore of the hole, which has added to it the decimal 0.003. This would indicate that the various dimensions given, with this one exception, are not of exceptional importance, or that the workman will be furnished with a special gage, or that the work will be jigged.

In this blueprint, it will be noted that the surfaces to be finished are indicated by the letter *f* placed on the working surface lines. As thus indicated, the base of the nut, the right-hand end, and the hole through the nut are to be finished.

PLATE II

BACK CLUTCH PINION

The lettered data at the upper edge of Plate II informs us that the piece is a back clutch pinion for a 5-foot boring mill and that one is required on each boring mill. Lettered data also tells us that the material is machinery steel and that the rough stock is $5\frac{1}{8}$ inches in diameter and $4\frac{1}{8}$ inches long.

The views given are a front view and a left end view. As the work is round with a plain squared-up right end, two views, as shown, are sufficient for the workman to understand what the piece is as well as to get all his dimensions. As an aid in reading the blueprint, the front view shows the piece as if it had been cut in halves through its length. The parts of this view which show where the cutting is made in solid stock are cross-lined at an angle of 45 degrees with the working lines. Referring to "Mechanical Drawing," Part I, page 35, it is seen that the cross-section lines are arranged to show that, as previously stated, the material is machinery steel.

As the first machine operation on this piece of work is that of getting a hole chucked through its axis, or length, the workman will naturally read his drawing for the size of the hole. At the right hand of the front view we find a dimension line with the

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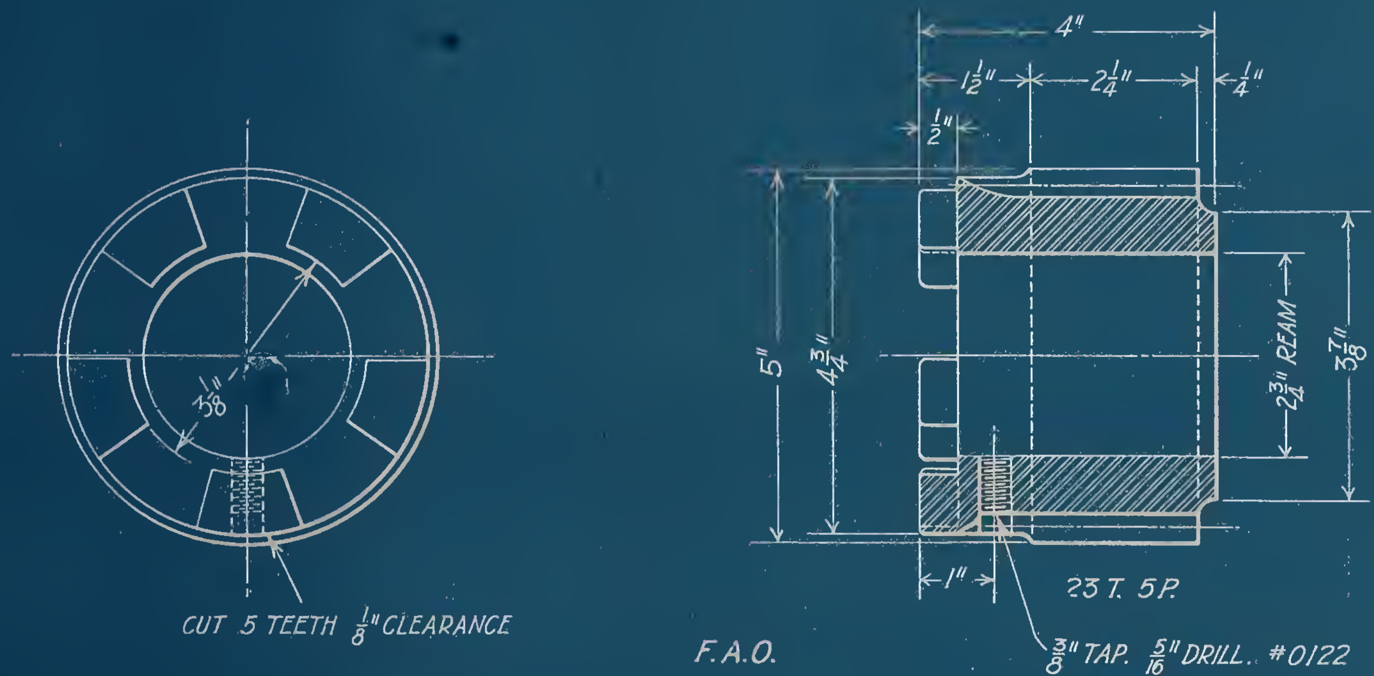
NAME OF PIECE	AMT. REQ.	NAME OF MACHINE	PIECE NO.
BACK CLUTCH PINION	1	5 FT BORING MILL	14141



APPROVED BY

	GROUP NO.	TRACED BY	DATE	CHECKED	THE CINCINNATI PLANER CO.	MATERIAL	USE PATT. NO.	SIZE	LENGTH	PIECE NO.
11	14004	N-i	5.9.17	F.a		M.S.		5 1/8"	4 1/8"	14141

arrow points touching the diameter lines of the hole extended, as explained in "General Directions for Reading Blueprints." The figures placed in the dimension line inform us that the hole is to be made $2\frac{3}{4}$ inches, and as the left end view shows a central circle, the hole is a round one. The word "ream" placed on the dimension line to the right of the dimension figures shows that the hole is to be drilled sufficiently small to permit it being reamed to its exact figured size. This dimension, as well as all the other dimensions, in the original blueprint, read two times the actual distance between the arrow points as shown on the views. The views in the original blueprint are then one-half the size of the actual piece of work and are drawn to one-half scale, in other words, 6 inches on a view represents 12 inches on the actual work.

The next two machine operations on this piece are to square the ends to the over-all length and to turn and finish it to the exact diameter. By following the end extension lines upward, we find at their upper ends a single dimension line having arrowheads with their points touching the extension lines. By reading the numeral placed in the line, it is found that the over-all length is 4 inches. Thus far this blueprint is very easily read.

Before starting work on the diameter, the views and the lettered text must be more carefully read. The name of the piece, "back clutch pinion," and a study of the views show it to be a gear with a clutch on its left-hand end.

Following out the extension lines to the left and to the right of the front view, which represent the several working diameters, we learn that the surface where the gear teeth of the pinion are to be cut is 5 inches in diameter. By following the upward extension lines, it is seen that the right-hand ends of the teeth do not start at the exact end of the stock but $\frac{1}{4}$ inch to the left of this. The extension lines also show by proper dimension lines that the faces of the teeth are to be $2\frac{1}{4}$ inches long. In this same view, the upward extension lines and dimension lines show that the remaining length of the piece from the left-hand end of the pinion teeth is $1\frac{1}{2}$ inches. Following the diameter extension lines to the left, we learn that the diameter of this part of the work is $4\frac{3}{4}$ inches.

A further study of the *left* end of the *front view* and of the *left end view* will show that the inner diameters of the clutch teeth are

counterbored out to $3\frac{1}{8}$ inches with a depth of $\frac{1}{2}$ inch. The right-hand end of the work is turned into the form of a hub having, according to the dimension line near that end, a small diameter of $3\frac{7}{8}$ inches but curving up into a fillet. Both views show that there is a tapped hole through one side of the piece, and the lettered data placed just below the front view tells us that the hole is to be drilled with a $\frac{5}{16}$-inch drill and tapped with a $\frac{3}{8}$-inch tap. Both views show the clutch teeth.

In the left end of the front view, extension lines carried upward have dimension arrowheads and numerals which show that the clutch teeth are to be cut $\frac{1}{2}$ inch deep. The left end view shows the general form of the clutch teeth. A lettered note just below this view states that there are to be five teeth and that the spaces between the teeth are to be $\frac{1}{8}$ inch wider than the teeth themselves. This indicates that the teeth in the mating part of the clutch and the teeth in the piece shown in this blueprint will, when in mesh, clear each other by a distance of $\frac{1}{8}$ inch. A lettered note placed just below the front view informs us that the gear teeth are twenty-three in number and that a five-pitch cutter is to be used in cutting them.

No finish *f* marks are placed on the various working lines in either view, but a lettered note *F.A.O.* tells us that the piece is to be finished all over. Two dotted lines on the front view indicate that there are hidden surfaces—in this case, the right-hand and the left-hand ends of the gear teeth of the pinion. If this text has been carefully studied, the reader will readily understand that Plate II really represents two pieces of work made solid in one piece of stock, namely, a toothed clutch and a pinion gear.

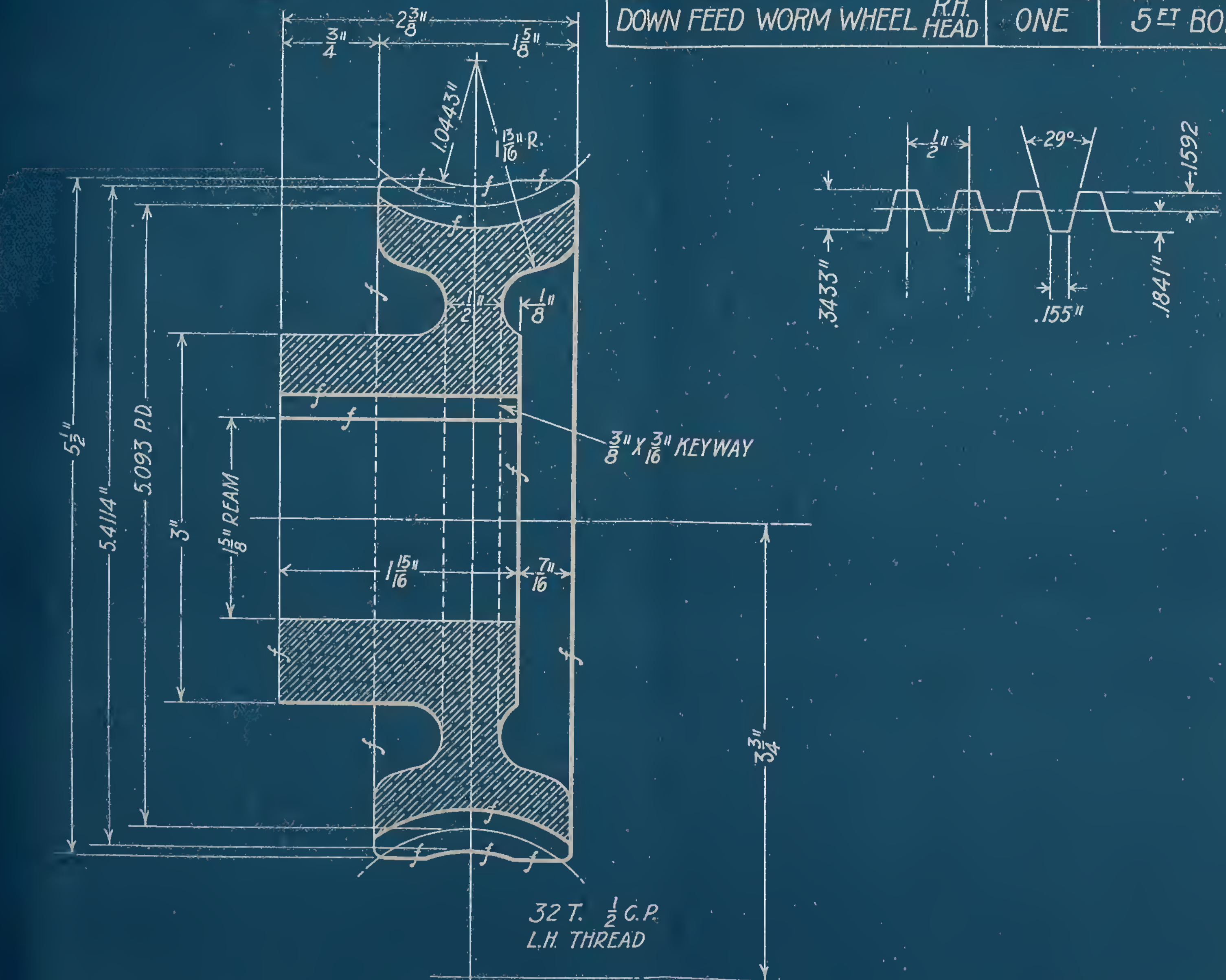
PLATE III

DOWN-FEED WORM WHEEL

In reading Plates I and II, it will have been noted that in Plate I three views were needed to show the workman all he needed, while in Plate II two views were sufficient. In Plate III a single view shows all that is needed to build this piece of work completely. The data on the upper edge of the blueprint states that the piece represented is a down-feed worm wheel for the right-hand head of a 5-foot boring mill and that one is required. The

III

NAME OF PIECE	AMT. REQ.	NAME OF MACHINE	PIECE NO.
DOWN FEED WORM WHEEL R.H. HEAD	ONE	5 FT BORING MILL	14061



APPROVED BY

GROUP NO.	TRACED BY	DATE	CHECKED		MATERIAL	USE PATT. NO.	SIZE	LENGTH	PIECE NO.
14011	R Gillham	4-19-17	F.A.	THE CINCINNATI PLANER CO.	BRONZE				14061

111

data on the lower edge tells us that the material is bronze, which is also indicated by the arrangement of lines in the cross-sectioning of the view.

A worm wheel is a toothed gear with the gear teeth cut at an angle with the sides of its rim. This angle is such as will make its teeth readily mesh, or fit, into the screw threads of the worm which is used to drive it. While the driving worm is not shown on this blueprint, a dimension line at the right of the view, with one of its arrow points touching the center line of the worm wheel and the other touching another center line drawn near the lower edge of the blueprint, shows that the center-to-center distance of the worm and the worm wheel is $3\frac{3}{4}$ inches. Lettered data near the lower center lines states that the worm wheel is to have thirty-two teeth of $\frac{1}{2}$-inch circular pitch and that the worm will have a left-hand thread, two threads to the inch.

In reading Plate III, let us first study the view itself. We will see that it is the view seen by a viewer facing the central axis of the piece and is, therefore, a front view. Lines drawn on the view at an angle with the working lines show that it is a sectional view, the piece having been cut along the center of its length precisely as a watermelon is sliced along the center of its length. Since the view is shown in this way, it is somewhat easier to read. The fact that one view only is given to work from indicates: (a) that if the work were viewed from its ends, the views would show on the blueprint as circles; and (b) that the ends of the work are plain and squared up—hub and rim. The lettered data, as already noted, states that the piece is a toothed gear wheel. Altogether, the piece is shown to consist of a hub, a rim, and a connecting web.

Following the upward extension lines and the dimension lines which they carry, it is seen that the over-all length of the piece is $2\frac{3}{8}$ inches and that the rim width is $1\frac{5}{8}$ inches. The upward extension lines and their dimension lines also show that the worm wheel hub extends, or projects, to the left of the rim a distance of $\frac{3}{4}$ inch. Dimension lines on the body of the view show: (a) that the wheel hub is $1\frac{15}{16}$ inches long; (b) that the rim overhangs the right end of the hub $\frac{7}{16}$ inch; (c) that the right end of the hub projects $\frac{1}{8}$ inch beyond the web; and (d) that the web is $\frac{1}{2}$ inch thick. Following the extension lines to the left of the view,

we learn that the hub is 3 inches in diameter and that the chucked hole in the hub must ream $1\frac{5}{8}$ inches. These extension lines also show that the over-all diameter of the toothed rim is $5\frac{1}{2}$ inches.

The curved diameter on the rim, as shown, is known as the throat diameter, to distinguish it from the over-all diameter. Following the extension lines to the left of the view, it is seen that the throat diameter is 5.4114 inches. The dimension line placed just over the rim with its arrow point touching the throat curve is drawn from the point where the short center line crosses the center line of the wheel rim. This dimension line indicates that the workman should machine the curved part, or throat, of the rim with a cutting tool having its cutting end formed to an arc of a circle of 1.0443 inches radius. The remaining radius dimension line has its arrow point resting on the curved working line which represents the inner surface of the wheel rim.

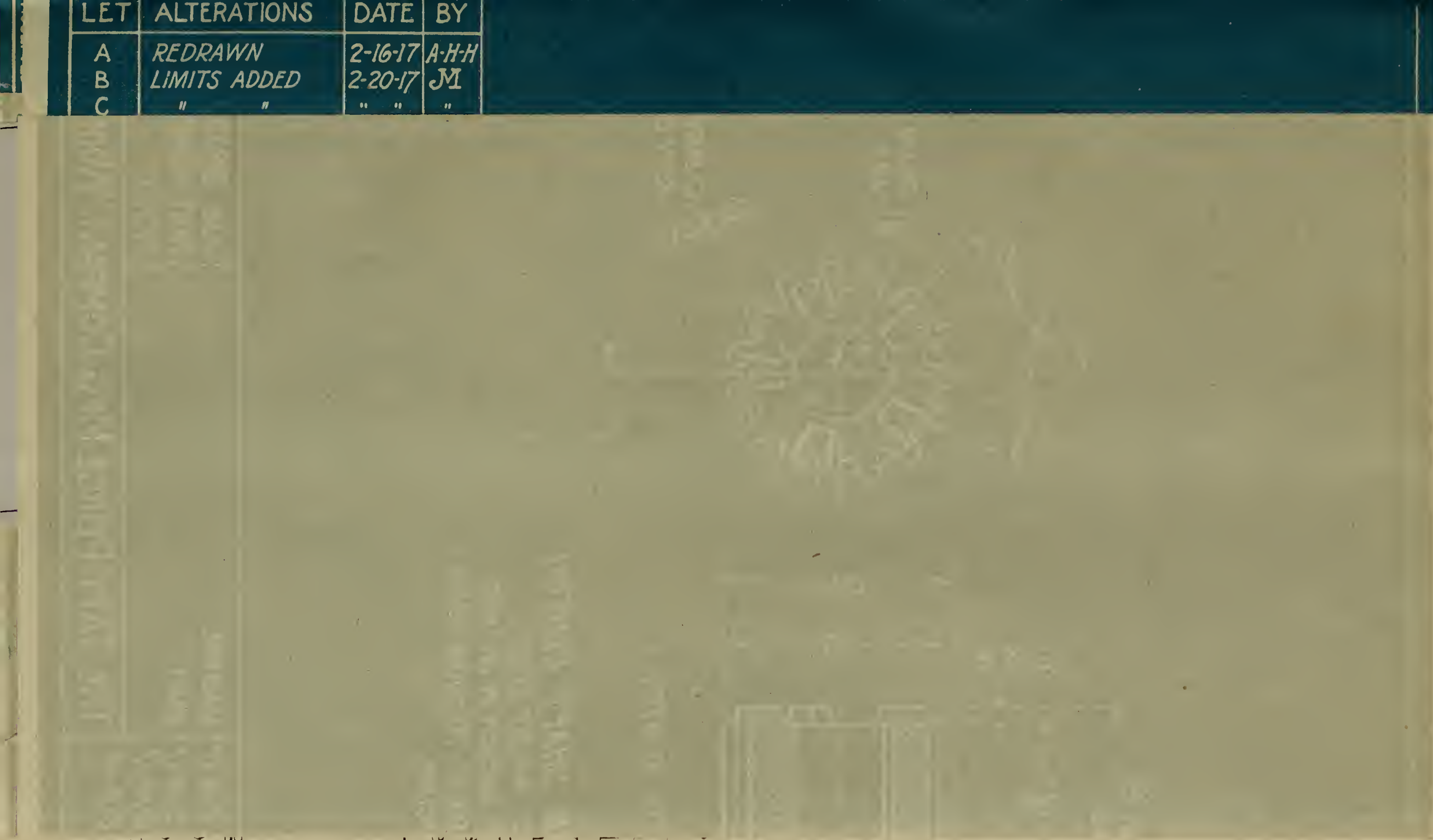
The teeth in worm wheel rims are invariably cut or machined by the use of a special tool known in shops as a *hob,* or a *hobbing cutter.* In using a hob to cut the gear teeth, the workman has to know to what depth the cutting teeth are to be sunk into the rim of the wheel. The sketch in the upper right-hand corner of Plate III indicates in outline the teeth, or threads, on the worm and on the hobbing cutter. This sketch shows: (a) the angle of the sides of the threads; (b) the center-to-center distance, $\frac{1}{2}$ inch; (c) the total depth of the hob thread, 0.3433 inch; and (d) the narrowest width of the hob thread and the space, 0.155 inch. The short note at the right of the view tells us that a keyway is to be cut in the surface of the hub hole $\frac{3}{8}$ inch wide and $\frac{3}{16}$ inch deep.

The *f* marks placed on the working lines of the view show that the sides and the outer surface of the rim and both ends and the hole through the hub are to be finished.

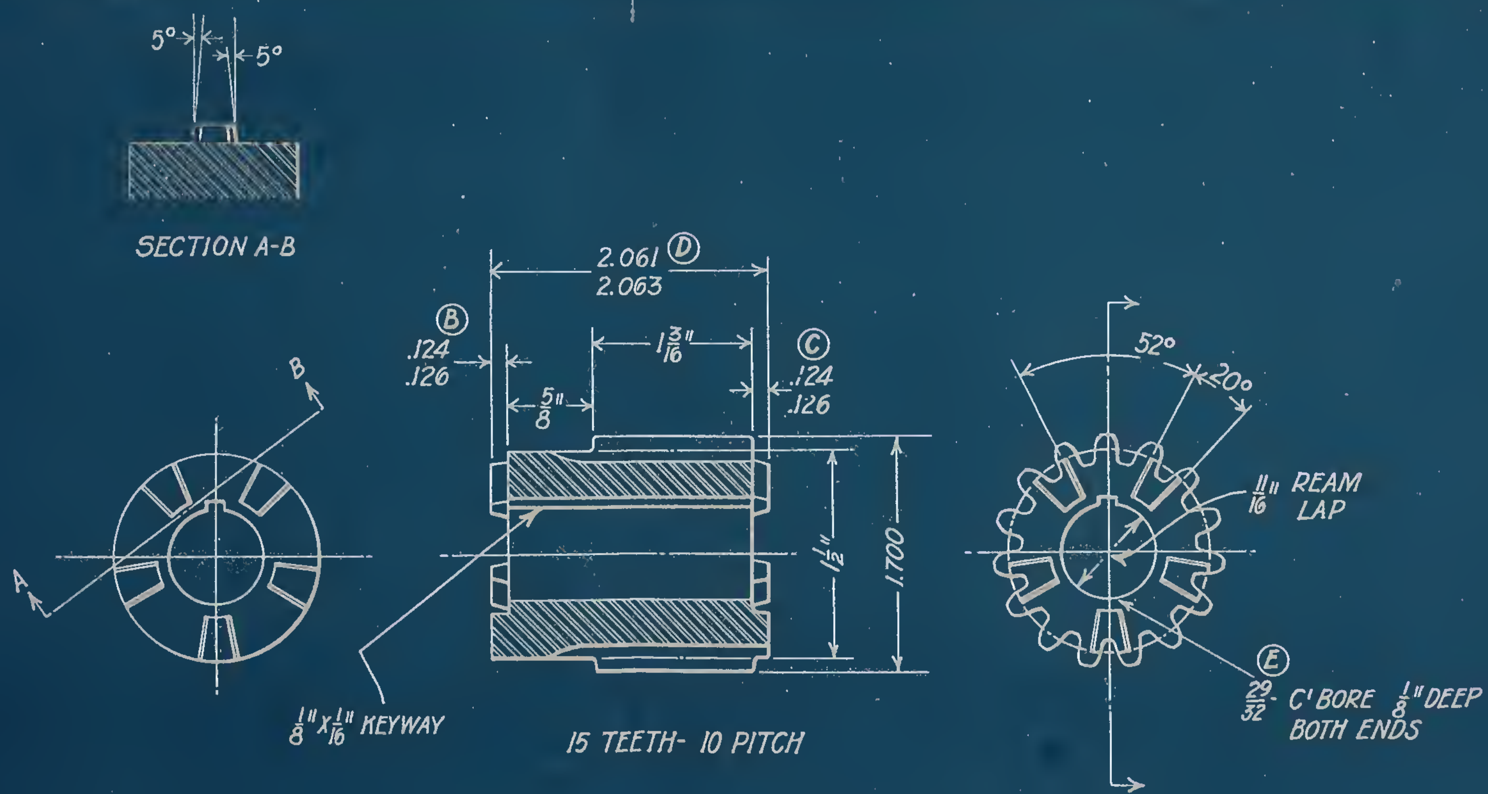
PLATE IV

INTERMEDIATE SHAFT CLUTCH

The piece shown in Plate IV is very nearly the same as that shown in Plate III. The practice is, however, that of another firm and the piece is represented by three views: a front view, a right end view, and a left end view. Reading the lettered data shows the piece to be an intermediate shaft clutch. The cross-section front


LET ALTERATIONS DATE BY
A REDRAWN 2-16-17 A·H·H
B LIMITS ADDED 2-20-17 JM
C " " " " "

212



INTERMEDIATE SHAFT CLUTCH

1- CARPENTER #5-317 STEEL
HEAT TO 1475°F. QUENCH IN OIL AND DRAW TO 550/560°F. TO SHOW 65/75 SHORE SCLEROSCOPE.

LET	ALTERATIONS	DATE	BY
A	REDRAWN	2-16-17	A.H.H.
B	LIMITS ADDED	2-20-17	J.M.
C	"	"	"
D	"	"	"
E	WAS $\frac{7}{8}$ C'BORE	2-9-18	J.B.A.

IV

DRAWN A.H.H.	DATE 2-16-17	MACHINE	JOB 2855	R.O.
TRACED A.H.H.	" 2-16-17	PART	PART NUMBER	
CHECKED J.B.A.	" 2-16-17		TICKET	
APPROVED R.W.	" 2-9-18	THE TAFT-PEIRCE MF'G. COMPANY, WOONSOCKET R.I. U.S.A.		
ACCEPTED	"			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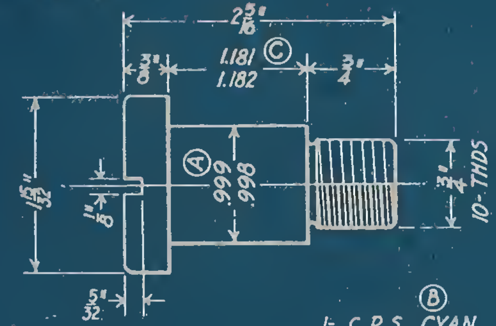
TRACED
CHECKED
APPROVED
ACCEPTED

LET	ALTERATIONS	DATE	BY
A	WAS 1.000 & .998	2-21-17	J.M.
B	CYAN ADDED	• • •	J.M.
C	LIMITS ADDED	6-25-17	

63



B
1- C.R.S. CYAN

V-1

DRAWN DATE
TRACED G·E·C " 11-17-16
CHECKED ADAMS " 11-22-16
APPROVED W.A.L. " 11-26-16
ACCEPTED "

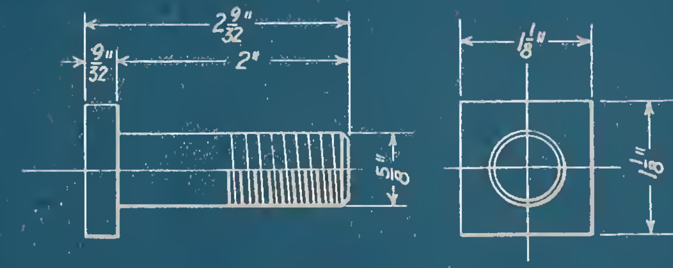
MACHINE SEMI-UNIVERSAL GRIND. MACH.
PART SWIVEL TABLE STUD

JOB 2855 R.O.
PART NUMBER 63
TICKET

THE TAFT-PEIRCE MF'G. COMPANY. WOONSOCKET, R.I. U.S.A.

LET	ALTERATIONS	DATE	BY

440



WHEEL GUARD T-BOLT
2- C.R.S.

V-2

DRAWN A.H.H. DATE 7-6-17
TRACED A.H.H. " 7-6-17
CHECKED ADAMS " 7-6-17
APPROVED W.A.L. " 7-10-17
ACCEPTED "

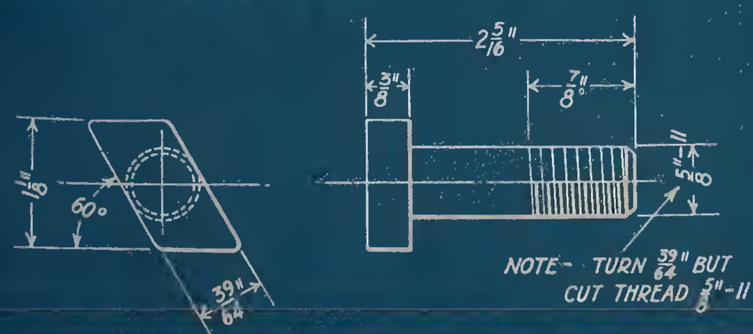
MACHINE
PART

JOB 2855 R.O.
PART NUMBER
TICKET

THE TAFT-PEIRCE MF'G. COMPANY. WOONSOCKET, R.I. U.S.A.

LET	ALTERATIONS	DATE	BY
A	TRACED	4-5-18	E.P.L.

113



NOTE- TURN $\frac{39}{64}$" BUT
CUT THREAD $\frac{5}{8}$"-11

DIAMOND TOOL POST T-BOLT
1- C.R.S. - CYAN

V-3

DRAWN DATE
TRACED E·P·L " 4-10-18
CHECKED ADAMS " 4-15-18
APPROVED W.A.L. " 4-15-18
ACCEPTED "

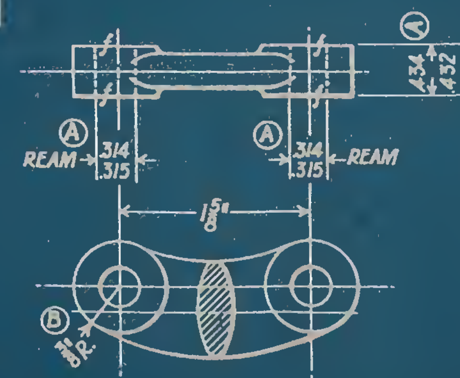
MACHINE
PART

JOB 2855 R.O.
PART NUMBER
TICKET

THE TAFT-PEIRCE MF'G. COMPANY. WOONSOCKET, R.I. U.S.A.

LET	ALTERATIONS	DATE	BY
A	DECIMALS ADDED	2-20-17	J.M.
B	ADDED DIM.	6-25-17	

345



CROSS FEED
CONNECTING LINK
1- C.I.

V-4

DRAWN DATE
TRACED HADLEY " 5-12-16
CHECKED ADAMS " 7-3-16
APPROVED W.A.L. " 7-6-16
ACCEPTED "

MACHINE SEMI-UNIVERSAL
PART GRINDING MACHINE

JOB 2855 R.O.
PART NUMBER 345
TICKET

THE TAFT-PEIRCE MF'G. COMPANY. WOONSOCKET, R.I. U.S.A.

view shows that the material is steel, and a further reading of the lettered note tells us that the company knows this steel as Carpenter No. 5–317 steel. The left end view shows the *general* form of the clutch teeth. A line drawn across this view near a single tooth shows that a section has been sliced off at this point. The line is lettered *A–B* at its opposite ends to enable the workman to find the view of the part sliced off.

Directly above the left end view is a small view named "section *A–B*". This shows a single clutch tooth viewed as if looked at from the inner, or small, end of the tooth. Extension lines projecting upward from the working lines of the tooth show that the tooth sides incline 5 degrees from the vertical. No other view shown tells us this, and therefore it is necessary for the workman to have this small section.

The right end view shows that the clutch teeth are slanted along their sides at an angle of 20 degrees, or, expressed another way, the sides of the clutch teeth make an angle of 20 degrees with each other. From a further study of this view, we learn that the inner surfaces of two adjacent teeth make an angle of 52 degrees. The lettered note at the right and the arrowhead tell us that the inner ends of the clutch teeth are counterbored $\frac{29}{32}$ inch in diameter and $\frac{1}{8}$ inch deep. Just above the front view at each end arrow points have the numerals 0.124–0.126. The decimal fraction for $\frac{1}{8}$ inch is 0.125; the numerals 0.124–0.126 then show that the $\frac{1}{8}$-inch depth must be cut to a tolerance of not more than 0.001 inch above or below the figured depth, $\frac{1}{8}$ inch. The right end view clearly shows that this shaft clutch has gear teeth in its outer surface, and data under the front view states that there are to be fifteen teeth, ten pitch. The only other note for the workman's use is that giving the size of the keyway.

PLATE V

DETAILS OF FOUR MACHINE PIECES

General Data. In the study of Plate V and of all succeeding plates, it will be assumed that the workman has thoroughly studied all that has gone before and understands what is meant by front, top, bottom, and end views, by sections, and by extension and dimension lines, and that he can find and read the dimensions.

Plate V is made up of four blueprints of small details and illustrates the way in which the Taft-Pierce Company send such into their shops. The number placed in the circle located in the upper right-hand corner of each small print is the part number of the piece and will be referred to in this text as the blueprint number. It will be noted that blueprints Nos. 63, 440, and 113 are all blueprints of bolts.

Swivel Table Stud. The piece shown in blueprint No. 63 is a swivel table stud for a semiuniversal grinding machine. A note placed just beneath the view states that the material is cold rolled steel, cyanide hardened. Only one view, a front view, is given, which indicates that the end views would show as circles. From this single view the workman can get all length dimensions and all diameter dimensions. Among the things to be noted in this blueprint are that the right end of the stud is to be threaded ten threads per inch and that some of the dimensions are given in pairs, for example, those of the body of the stud. This means that the length of the body and the diameter of the body, respectively, must lie within the given pair of figures for that dimension. Take the case of the body diameter; it must not be greater than 0.999 inch nor smaller than 0.998 inch, a tolerance of one-half of one-thousandth inch above or below a central dimension.

Wheel Guard T Bolt. Blueprint No. 440 is a wheel guard T bolt, and the note tells us that two are required and that the material is cold rolled steel. A front and a right end view are given. If a single front view of this piece were shown, the workman would infer that the bolt head was a circle; the end view shows that the bolt head is square. A left end view instead of a right end view would indicate this equally well, but in that case the circles which represent the body of the bolt would be dotted circles instead of showing as they do in the right end view. There are no finish *f* marks in either view because the piece, as noted, is made from cold rolled steel bar stock, which has a finished surface, and when the bolt is turned to size, the outer surfaces of the head have the original finish of the bar. Moreover, to construct the rest of the bolt naturally finishes those parts.

Diamond Tool Post T Bolt. Blueprint No. 113 is a diamond tool post T bolt, and the lettered note states that one is required

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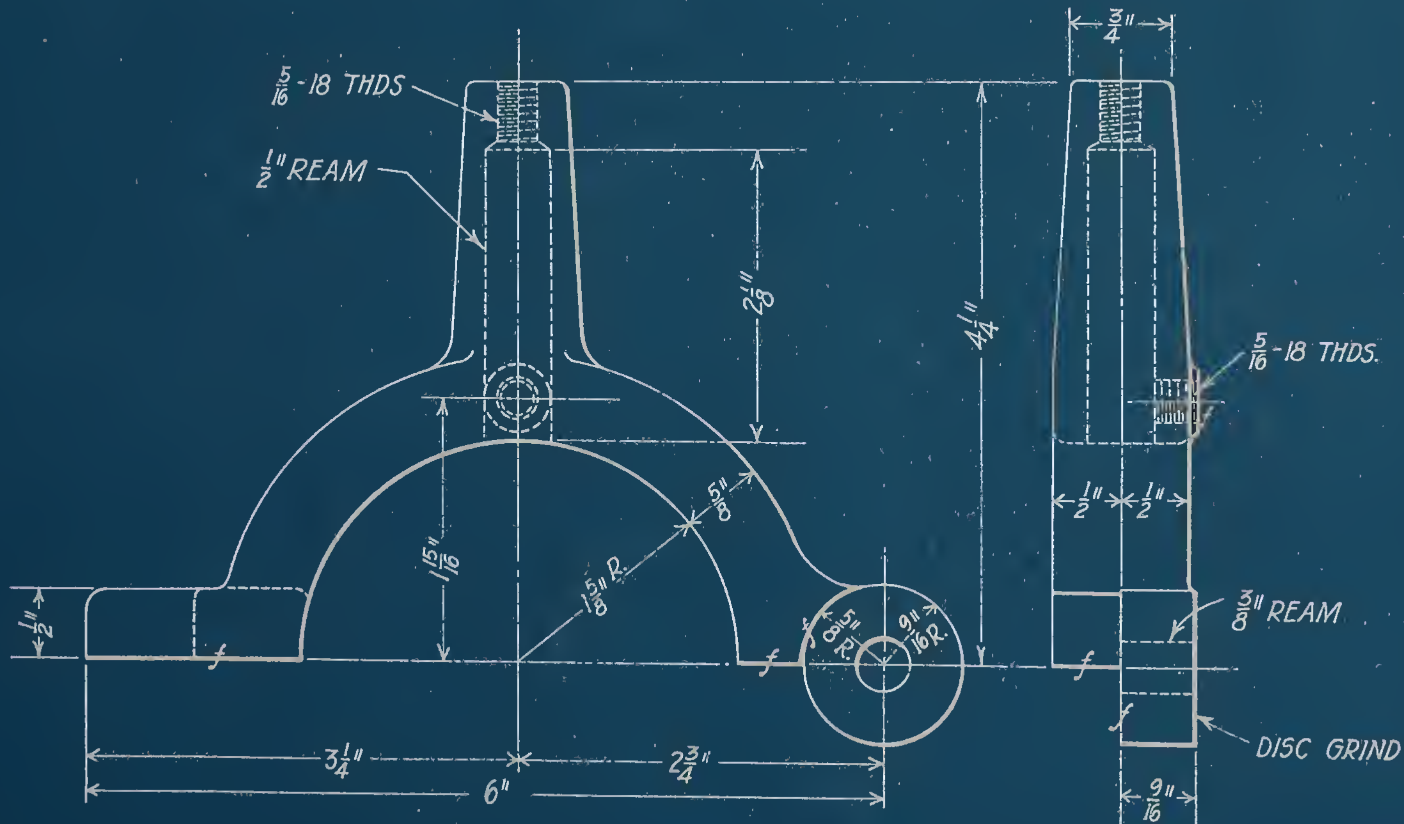

CENTER REST TOP
1- CAST IRON

LET	ALTERATIONS	DATE	BY
A	V1		

DRAWN *Jennings* DATE 3-24-17	MACHINE	JOB 2855	R.O.
TRACED "	PART	PART NUMBER	
CHECKED *J.B.A.* " 4-2-17		TICKET	
APPROVED "			
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THE TAFT-PEIRCE MF'G. COMPANY. WOONSOCKET R.I. U.S.A.

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and that the material is cold rolled steel, cyanide treated. Two views of this piece are necessary. The views differ from those shown in blueprint No. 440, since the view showing the bolt head is a left end view. Placed in this way, the circles which represent the body part of the bolt show as dotted circles. Another interesting thing is that the body dimension of the bolt is given by the dimension figures as $\frac{5}{8}$ inch, while a lettered note with an arrowhead tells us that the body of the bolt is turned to a diameter of $\frac{39}{64}$ inch and that the threaded part is $\frac{5}{8}$ inch in diameter and has eleven threads per inch. The end view shows that the bolt head inclines at an angle of 60 degrees with the base line.

Cross-Feed Connecting Link. Blueprint No. 345 shows a front view and a top view of a cross-feed connecting link. One only is required and both the lettered note and the arrangement of cross-section lines inform us that the material is cast iron. Where the shape of the cross-section is simple, as shown, it is usual to place it directly on one of the views rather than make an additional view. The cross-sections of pulley arms, connecting rods, and links are generally shown by this method. The workman in reading this blueprint should note that the reamed holes have limiting dimensions given and also that the thickness of the hubs is held to a small tolerance. The finish *f* marks clearly show what surfaces are to be machined.

PLATE VI

CENTER REST TOP

The lettered data states that Plate VI is a blueprint of a center rest top. One is required and the material is cast iron. A short study will show the machinist that many of the dimensions are given to or from horizontal or vertical center lines; also that some of the dimensions are plain distances, in which case the dimension line has an arrow point at each end, while others are from a center point and give the radius from that point of the working line which represents the surface. When a radius dimension is given, it is usual to place the initial letter *R.* or the letters *Rad.* after the dimension figures.

In the front view, the workman should especially note that the hole through the length of the upper part of the piece is to

be drilled and reamed a part of the way and drilled and tapped eighteen threads per inch for the rest of its length. Another important item is that, while the radius of the hub is given as $\frac{9}{16}$ inch, the frame back of the hub is machined back to a radius of $\frac{5}{8}$ inch.

In the right end view, the things which the machinist should especially note are that one end of the lower hub is marked *f*, while the opposite end is marked "disc grind", indicating that the *f* end is to be carefully finished to an accurate bearing, while it is not necessary to be so particular with the opposite end. The end view also shows that the hole in the hub is to be drilled and reamed. The hole just above the hub is to be drilled and tapped for a $\frac{5}{16}$-inch screw, eighteen threads per inch.

PLATE VII

CENTER REST BASE

A reader of this text who is familiar with machine work knows that a center rest is a fixture used in turning or grinding to give support and steadiness to long or slender work. Plate VIII gives a complete view of a center rest and indicates its use and, before taking up a study of Plate VII, it will be well to glance at Plate VIII.

The lettered title of Plate VII states that it is the blueprint of the center rest base. One is required and it is made of cast iron. The piece of work shown is then the mate of that shown in Plate VI and some of its features and dimensions are the same. A complete front view and a complete right end view are given as well as a portion of a top view, which is placed directly above the left upper corner of the front view.

The working lines of the bottom of the front view and the end view show that the base is provided with a squared projection used to locate the center rest on the bed of the machine. Aside from this, the machinist should notice the data which relates to finishing the small hub at the top of the end view and at the upper right corner of the front view. The term "spot face $\frac{7}{8}''$" indicates that the surface touched by the arrow point is to be finished, by using a counterbore $\frac{7}{8}$ inch in diameter, to the limiting thickness given just above the end view. It should be noted that

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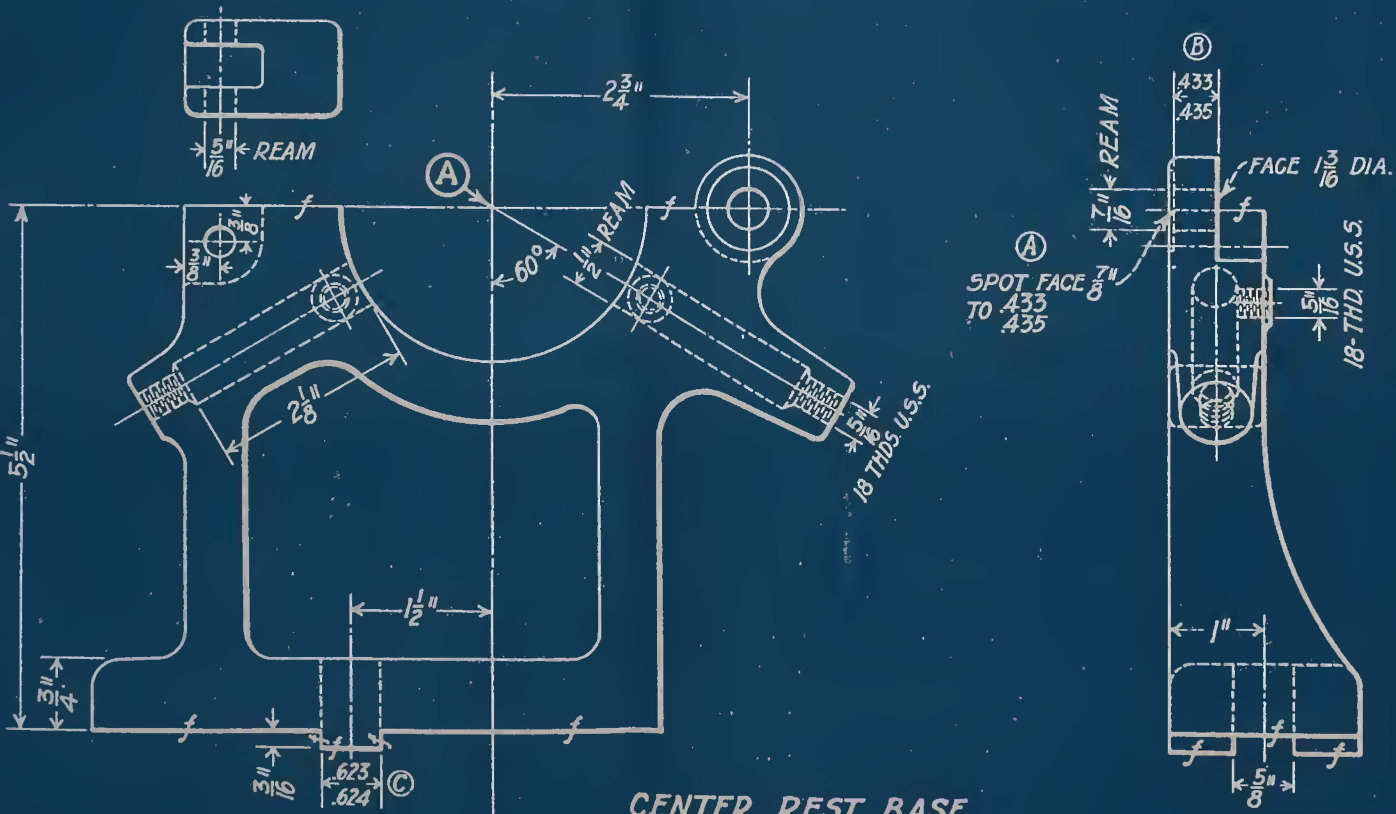
B	DIM. CHANGE		
C	LIMIT ADDED	2-26-17	JMT

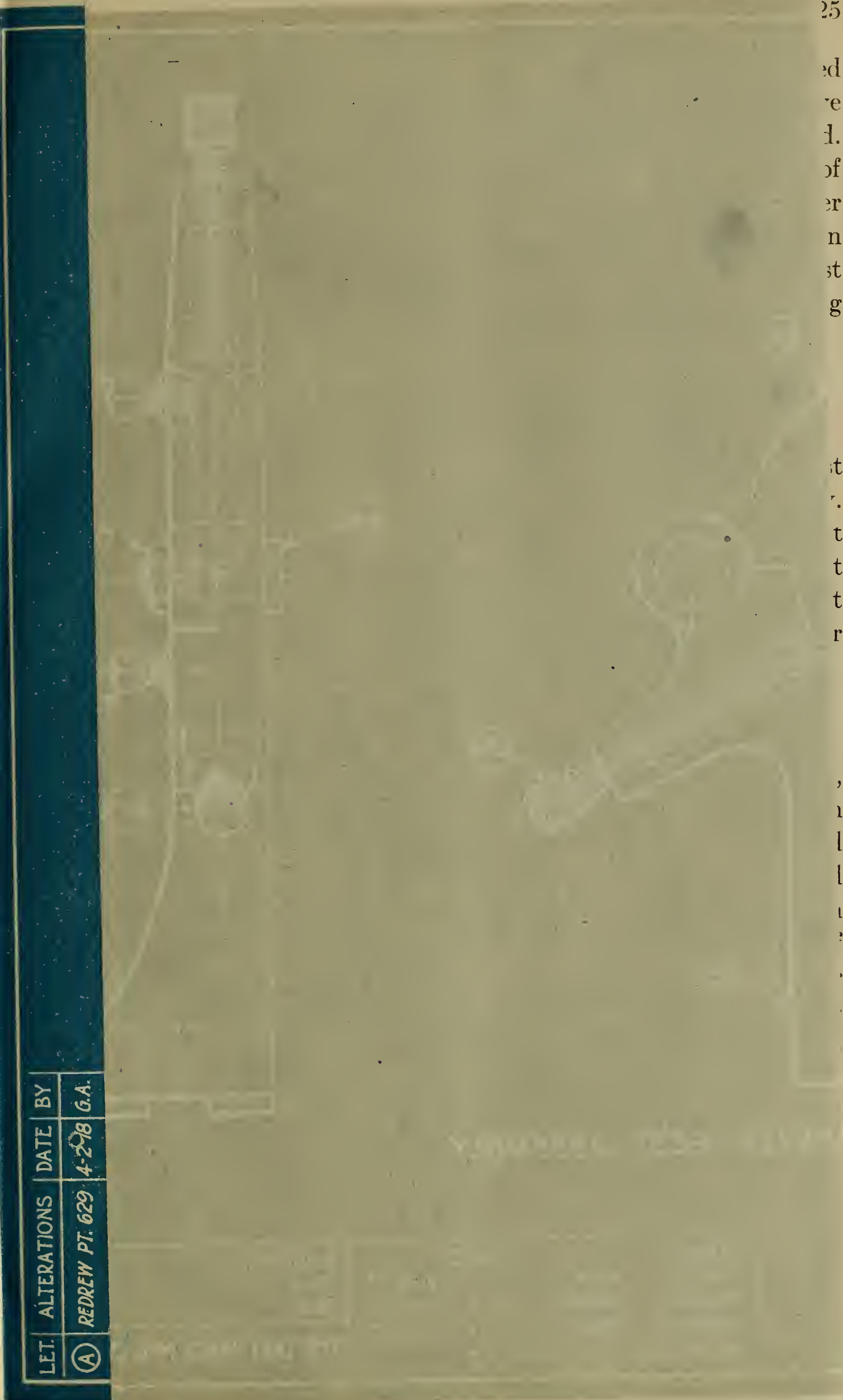


CENTER REST BASE
1- C.I.

LET.	ALTERATIONS	DATE	BY
A	NOTE ADDED		
B	DIM. CHANGE		
C	LIMIT ADDED	2-26-17	J.H.T.

VII

DRAWN	G.R.	DATE 4-24-17	MACHINE	JOB 2855 R.O.
TRACED		"	TOOL	TOOL NUMBER
CHECKED	ADAMS	" 4-27-17	PART	TICKET
APPROVED	mas	" 4-27-17	THE TAFT-PIERCE MFG. COMPANY, WOONSOCKET, R.I. U.S.A.	
ACCEPTED		"		


LET.
ALTERATIONS
DATE
BY
REDREW PT. 629
G.A.

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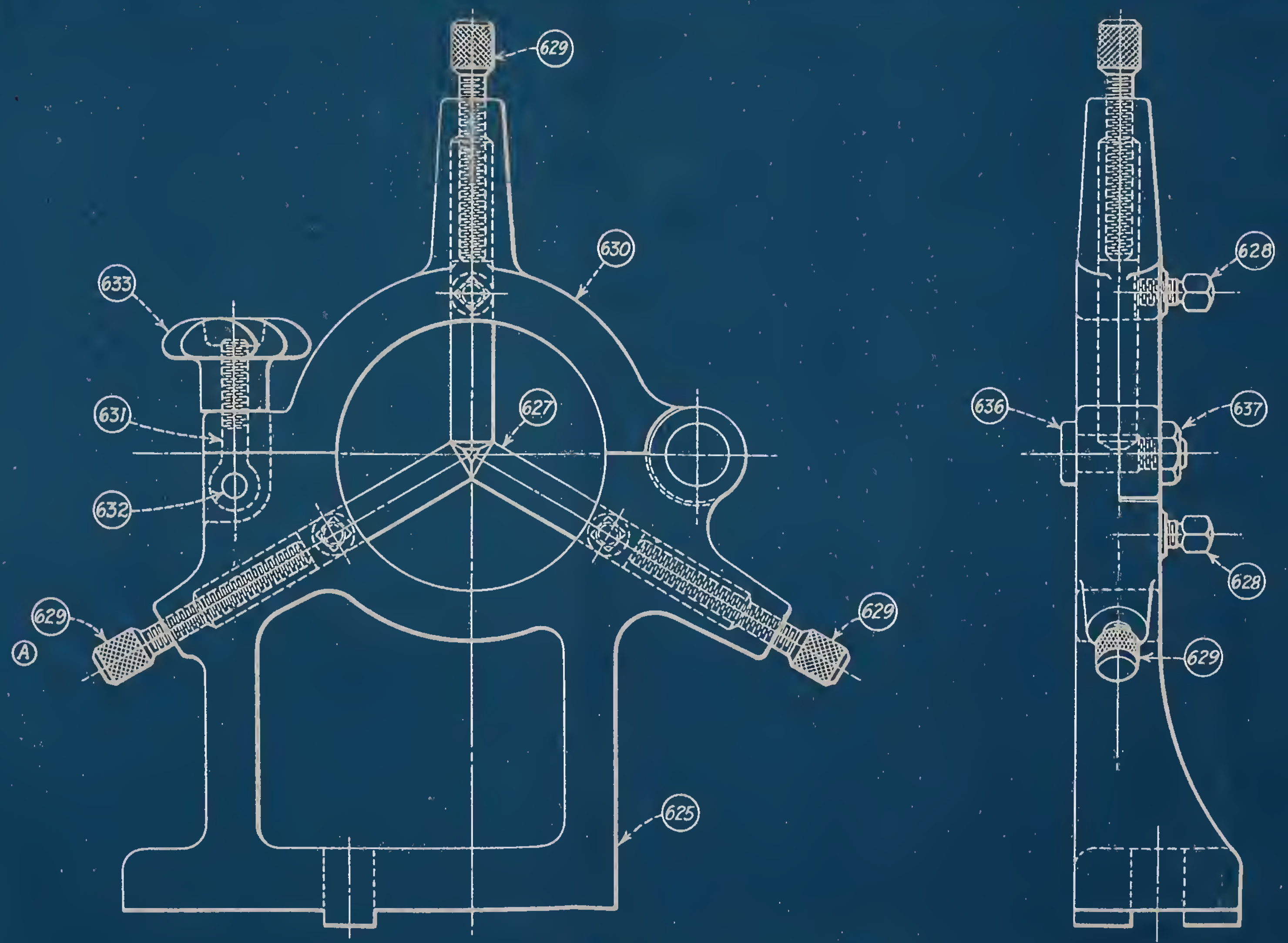

CENTER REST ASSEMBLY

LET.	ALTERATIONS	DATE	BY
A	REDREW PT. 629	4-2?-18	G.A.

VIII

		DATE		
DRAWN			MACHINE	JOB 2855 R.O.
TRACED	A.H.H.	" 4-24-17	TOOL	TOOL NUMBER
CHECKED	ADAMS	" 4-27-17	PART	TICKET
APPROVED	mas	" 4-27-17	THE TAFT-PIERCE MF'G. COMPANY. WOONSOCKET, R.I. U.S.A.	
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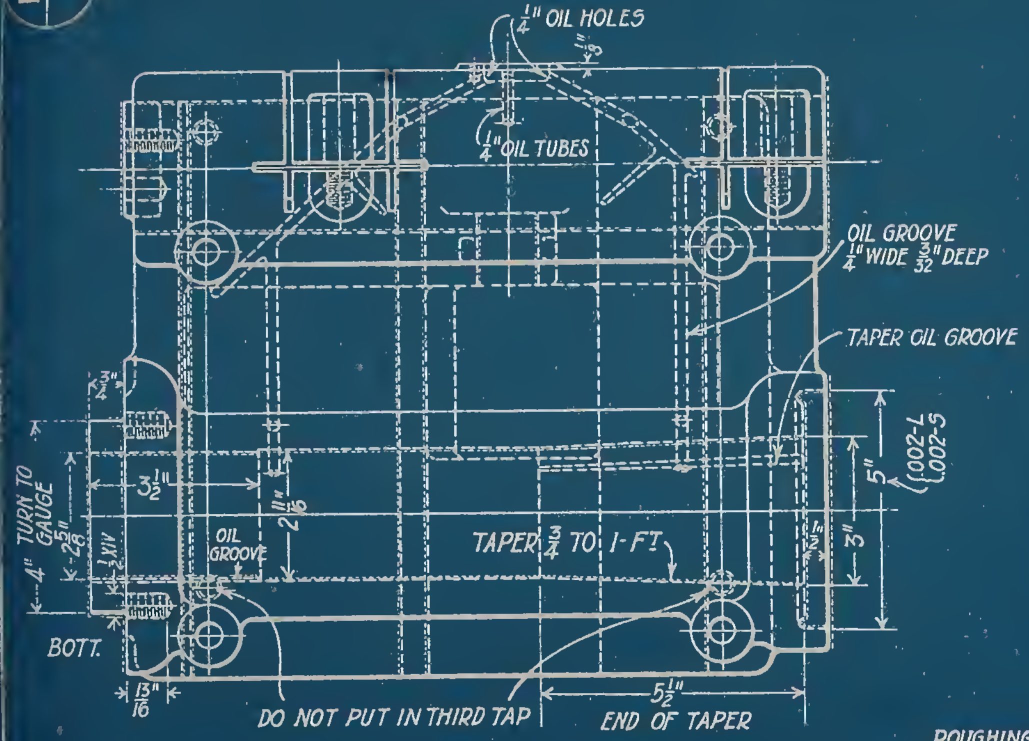
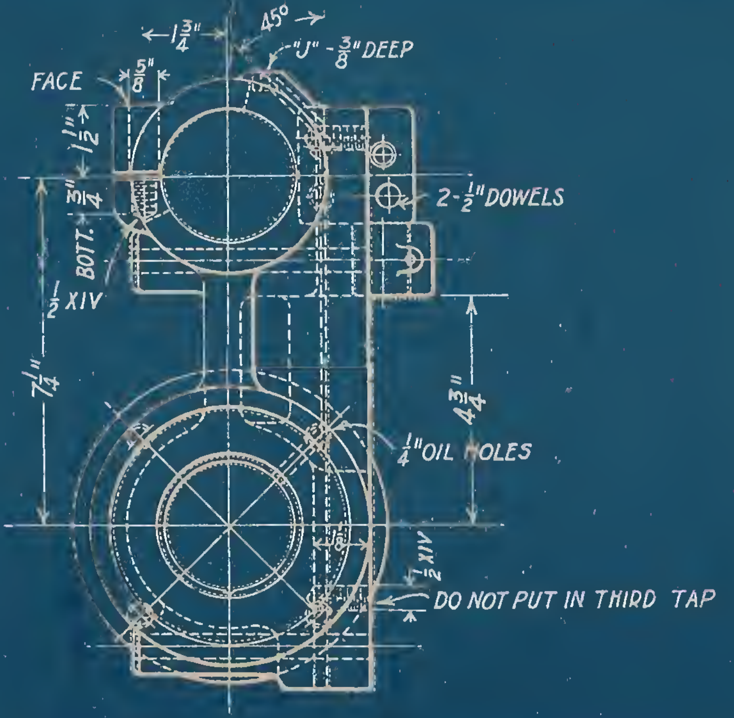
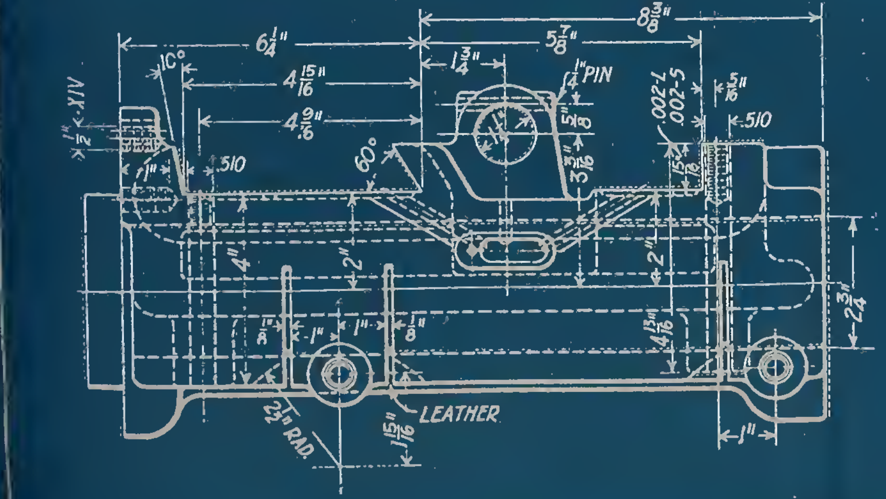






ROUGHING CUTTERS FOR WAYS
PLUG GAUGES FOR STRAIGHT BEARING
PLUG GAUGES FOR WORK SPINDLE HOLE
SHELL REAMER FOR WORK SPINDLE HOLE
JIG FOR ELEV. SCR. NUT HOLE
TEST BAR FOR SCRAPING
DRILLS & REAMERS
JIG FOR DRILLING
FORM TOOL FOR REAMER
GAUGE FOR WAYS
FIXTURE FOR ROUGH MILLING
FIXTURE FOR FINISH MILLING
CLAMPS

WORK SPINDLE SLIDE

1-C.I. $\frac{P13}{133}$

SCALE $\frac{1}{2}$ SIZE

TIME	P 13	LOT	

NO. 13 AUTO. GEAR CUTT. M'CH.

WORK SPINDLE SLIDE

DATE OCT. 29 1915 Syl. Bennett EX. A.B.C.

BROWN & SHARPE MFG. CO.,

PROVIDENCE, R.I.

P13
16

1X

certain of the holes are drilled and reamed while others are drilled and threaded with a tap. The machinist should carefully observe on which of the working lines of the views the *f* mark is placed. He should also note in Plate VII, as in Plate VI, that many of the dimensions are given to or from horizontal or vertical center lines and that all dimensions bear a certain relation to a common center, or axis, *A*. In reading the dimension figures, the machinist will find that several of them have a limiting error tolerance telling him that he must be especially accurate in those dimensions.

PLATE VIII

CENTER REST ASSEMBLY

Plate VIII shows two views, and the lettered title placed just below the views states that the piece is a center rest assembly. The two views furnish a line picture of the completed center rest and show all its separate parts as they are when *assembled* or, as it is often termed, *set up*. It will be noted that each and every part is given a number. These numbers are known as the piece, or part, numbers.

PLATE IX

WORK SPINDLE SLIDE

Compared with many of the blueprints shown, Plate IX, showing the work spindle slide, is difficult to read and it has been selected to illustrate a fairly complicated and irregularly shaped piece. As an aid in reading this blueprint, a short study should be made of the general form and shape of the piece as shown in outline in the front, right end, and top views. An examination of the views shows that the piece consists in general of two hubs, or cylinders, with holes through their length. The cylinders are placed with the smaller above the larger and are connected by a short web running their entire length. When the reader clearly sees this and has the picture clearly in his mind, he can then study the various small hubs, bosses, and other pieces attached to the two long hubs and their connecting flange.

In tracing the location and shape of the several parts, holes, etc., it should be kept clearly in mind that each part in the front view, if shown in the top or in the end view, will be squarely above or squarely to the right of its position in the front view.

Another thing which aids the reader in getting a picture of the piece in mind is its name, "work spindle slide." The note just over the name plate, "Scale Half Size," of course applies to the original blueprint only and not to the reproduction in this text.

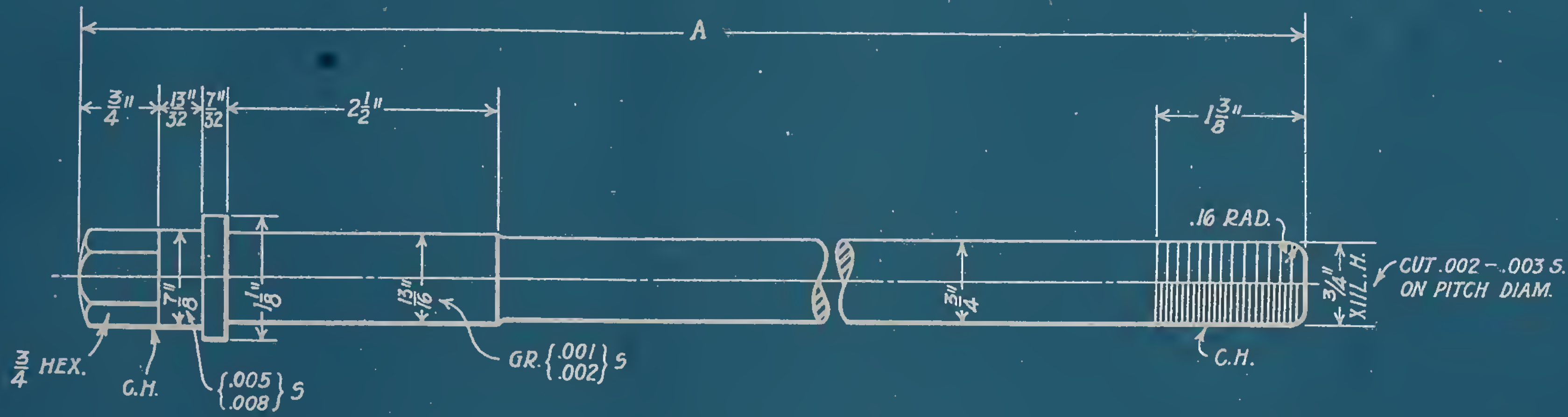
Several helps in the form of lettered notes are on this blueprint. As an example, attention is called to a note at one end of the front view which tells us that the dotted lines on which the arrow points touch represent oil grooves $\frac{1}{4}$ inch wide and $\frac{3}{32}$ inch deep. From a study of the upper part of the front view and of the end view we learn at which points the oil grooves start and also that they are drilled at an angle of 45 degrees to reach the surfaces of the slide bearings.

Among the specially important things to be noted is that, while the hole through the length of the smaller of the two long hubs is a straight plain cylindrical hole, the hole through the larger is tapered at its right-hand end $\frac{3}{4}$ inch to the foot for a distance of $5\frac{1}{2}$ inches. Attention is also called to the two slide bearings on the rear side of the work, one slide bearing having right-angle sides and the other a 60-degree side. Threads per inch on blueprints at the shops of the Brown & Sharpe Manufacturing Company are invariably given by Roman numerals. For example, as may be noted on the blueprint, a hole threaded fourteen threads per inch is marked *XIV*. Also, each surface which is to be finished is indicated by drawing a brilliant red line close beside the working line which represents the surface. On this plate and on Plates XII and XIII these lines are shown dotted and are drawn close to the finished surface lines. Lettered notes placed on this blueprint state what special tools should be got from the tool room before starting the work.

PLATE X

DRAWING-IN BOLT

Plate X shows a drawing-in bolt, and the lettered note just below the name tells us that one is required, that the material is cold rolled steel, that it is a forging, that it is forged on a heading machine, and that it is to be casehardened as shown. The fact that the forging is done on a heading machine indicates that the head end only is upset to its rough shape. The letters *C.H.*



DRAWING IN BOLT

1- C.R.S. A2278 A, B, C. FORGING.
CASE HARDEN AS SHOWN.
FORGED ON HEADING MACHINE.

STOCK

A 2278 A	DIA.	LONG
A 2278 B	DIA.	LONG
A 2278 C	DIA.	LONG

SYMBOL A 2278 A A = $25\frac{7}{8}$"
USED ON C2

SYMBOL A 2278 B A = $29\frac{15}{16}$"
USED ON C3

SYMBOL A 2278 C A =
USED ON C5

TIME	A2278	LOT	

C2, C3, C5,

DRAWING IN BOLT

DATE APRIL 23 1917. A.P.D. EX. R.S.L.

BROWN & SHARPE MFG. CO.,
PROVIDENCE, R.I.

A2278	B.P.G.

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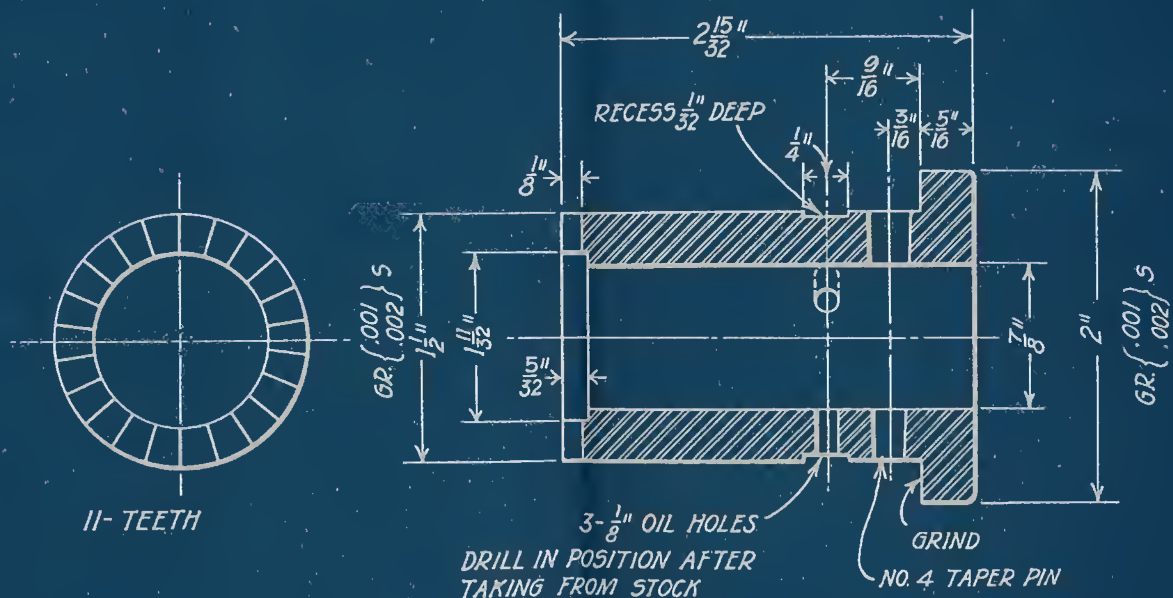
XI

DEVELOPMENT OF CLUTCH TEETH
SPACES .005 WIDER THAN TEETH



KNEE SHAFT CLUTCH
M.S.
FORMED TOOL # 9846

STOCK :-
2 1/16" DIAM. X 2 9/16" LONG

TIME	A2227	LOT	
A3, AA3, BBH2, B3, BB3, C2			
KNEE SHAFT CLUTCH			
DATE DEC. 28 1916 H.G. EX. A.H.C.			
BROWN & SHARPE MFG. CO. PROVIDENCE, R.I.			
A2227	B.P.G.	W.R.P.	

X1

placed just below the threaded end and just below the $\frac{3}{4}$-inch hexagon end show that the bolt is to be casehardened at these places, according to the lettered notes. One view only is given, which indicates that an end view would show circles unless otherwise specified. A note at the extreme left end of the view states that the end is made a $\frac{3}{4}$-inch hexagon.

All length dimensions are easily read with one exception, that of the over-all length, which is represented by the capital letter *A*. Notes lettered on the blueprint at the lower right-hand corner inform us that, when this bolt is made for and used on C2, *A* is $25\frac{7}{8}$ inches in length, and when it is made for and used on C3, *A* is $29\frac{15}{16}$ inches. While all the diameter dimensions are easily read, the machinist should surely note that several of them have lettered notes giving additional information. For example, we read that the $\frac{13}{16}$-inch diameter is to be ground 0.001 or 0.002 inch small, "Gr. $\left\{\begin{matrix}.001\\.002\end{matrix}\right\}$S." In this blueprint, the letters *Rad.* are used instead of the capital letter *R.* to denote a radius.

PLATE XI

KNEE SHAFT CLUTCH

The title plate at the lower right of Plate XI tells us that the piece of work shown is a knee shaft clutch. Further information given on the title plate indicates that this clutch is used on A3, AA3, BBH2, etc. A lettered note placed on the blueprint just below the two views states that the knee shaft clutch is to be made of machinery steel, that the rough stock is a piece measuring $2\frac{1}{16}''\times2\frac{9}{16}''$, and that a certain formed tool is used by the machinist. All the length and all the diameter dimensions are easily found and read, while a copious use of notes gives the machinist much special information. For example, a lettered note placed just below the front view tells us that a certain hole is drilled in position after the piece is taken from stock. This indicates that when finished by the machinist to be placed in stock, this hole is left off and that when the setting-up man gets the piece from the stockroom, he places it in position and then drills it in place. Before starting work on this piece, the machinist should read all notes. The front view is a complete section.

In this blueprint, the information concerning the clutch teeth is contained in a small view placed somewhat above the front view and named a "development of clutch teeth." This view represents the outer surface of the clutch teeth rolled out on a flat surface, as explained in "Mechanical Drawing," Part III, page 107. The note tells us that the spaces between the teeth are 0.005 inch wider than the teeth. The view also shows that the sides of the teeth slant to an angle of 5 degrees. The end view is sufficiently complete to show the form of the clutch teeth only, a lettered note placed just below the view giving the number of clutch teeth as eleven. As both views show that the piece of work is by construction finished all over inside and out, no finish needs to be indicated.

PLATE XII

BACK TOOL POST

The title plate informs us that the piece shown in Plate XII is the back tool post and that there are a set of tool posts. A lettered note placed at the upper right tells us that the tool post material is M.I. and that it is to be casehardened to have a mottled surface. This plate, like Plate IX, lists up the special tool-room tools for the job. The views given are front, top, and end views supplemented by a small section view, placed just above the right end view, showing a section on line *A–B*.

This small *A–B* section shows that the bottom of the large slot running through the tool post is at an angle of 5 degrees with the back surface of the slot. The working lines of this slot, as shown in the front and the end views, indicate that the top surface of the slot is parallel to the top surface of the tool post and that the lower, or bottom, surface of the slot makes an angle of 20 degrees with a center line drawn parallel to the upper surface of the slot. Working lines, drawn as full lines in the front and the end views but dotted in the top view, show a projecting feather on the under side of the tool post base. Clearly defined dimension lines and figures give the width, depth, and length of the piece. The machinist should note that the width is to be made standard 0.001 inch small; also that certain base surfaces are to be surface ground.

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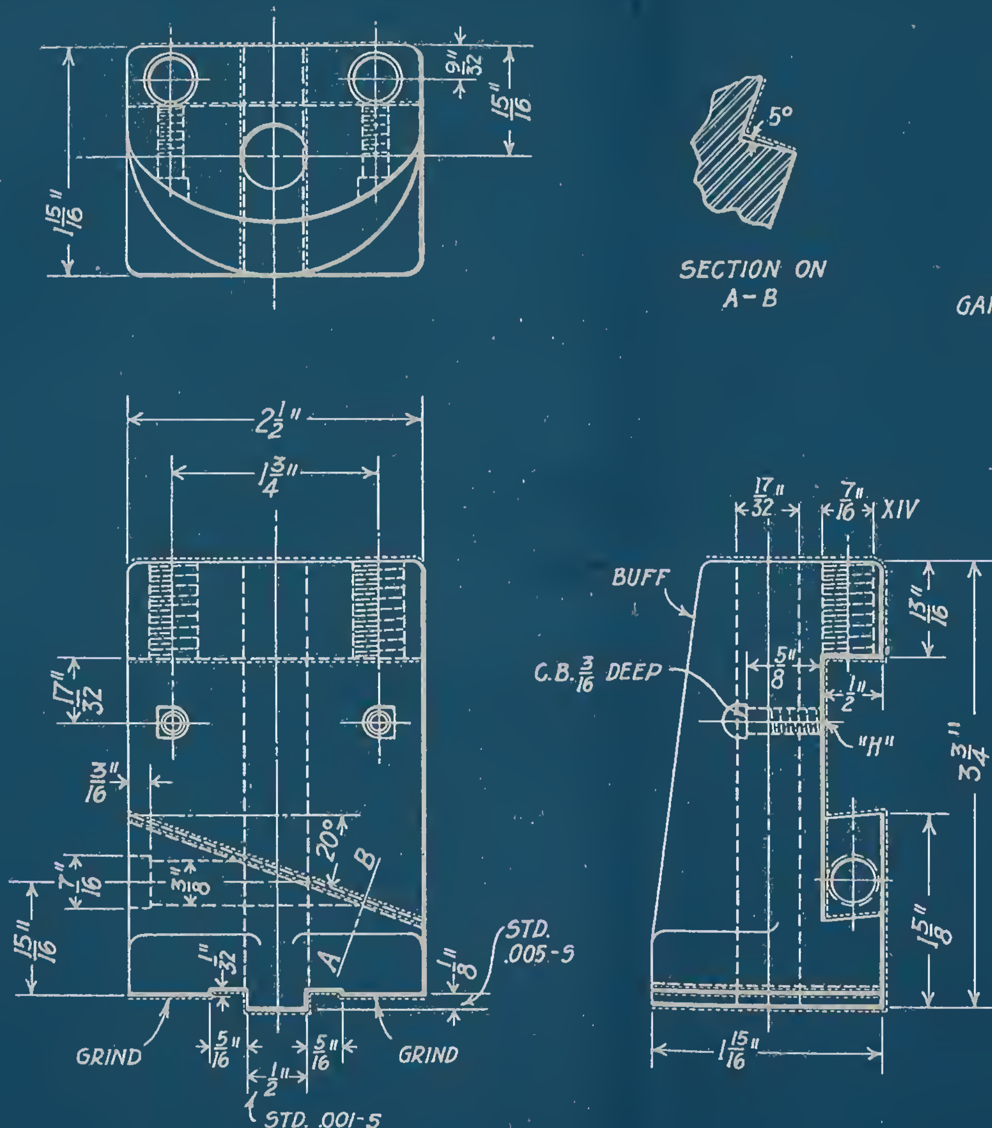
FG2 3



TOOL POST (BACK)

1-M.I.-C.H. MOTTLED $\frac{FG2}{2}$

JIGS FOR DRILLING # 11944 & 11944-2
FIXTURE FOR MILLING WEDGE SLOT # 11943 & 11943-1
FIXTURE FOR MILLING BOTTOM # 11959
GANG OF 3 CUTTERS FOR MILLING SLOT # 9177-# 9178-# 9180
ANGULAR CUTTERS # 11937
CUTTERS # 11942
SPECIAL VISE FOR 20° { # 11980, # 11980-1, # 11980-4 }

SYMBOL FG2-B

TIME	FG2	LOT	

SET OF TOOL POSTS

TOOL POST (BACK)

DATE APRIL 19 1916 J.P.R. EX. ~~2.22~~

BROWN & SHARPE MFG. CO.,
PROVIDENCE, R.I.

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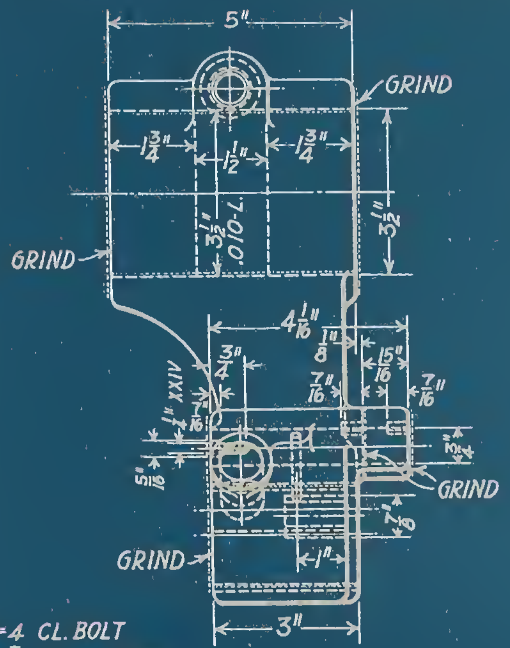
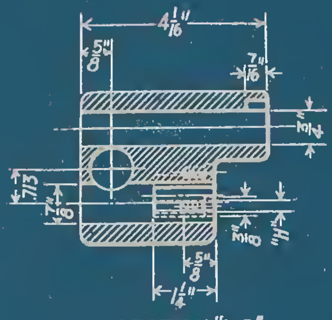
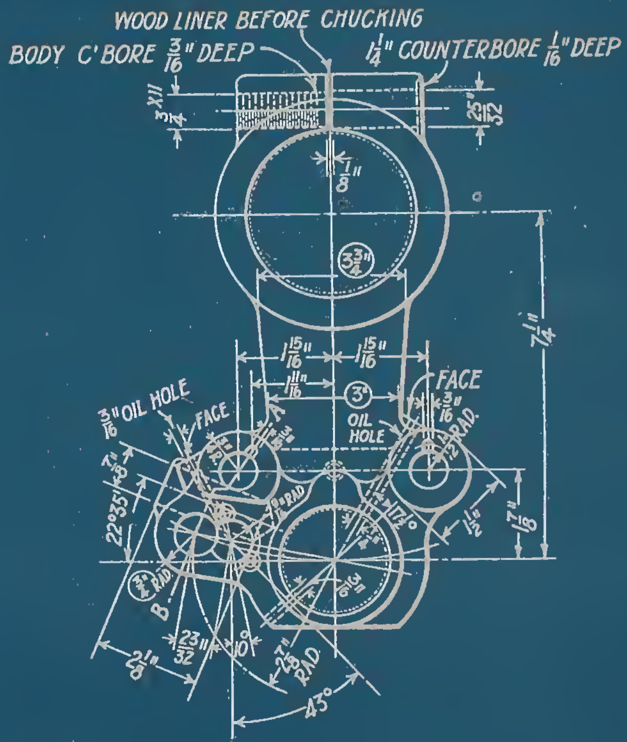






FURNISH :-

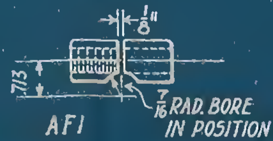
1- STY. 3 $A=\frac{3}{4}$ $B=4$ CL. BOLT
2- STY. 20 A="H" $B=\frac{7}{16}$ CEN. A. BUSH.
1- STY. 27 $A=\frac{1}{4}$ $B=\frac{1}{2}$ CL. PLATE
1- STY. 56 $A=\frac{3}{16}$
1- STY. 56 $A=\frac{1}{4}$
1- STY. 89 $B=\frac{3}{4}$ #2- ADJ. WORM
2- STY. 90 $A=\frac{3}{16}$ $B=\frac{3}{8}$ ARM S.CL. BOLT
1- STY. 90 $A=\frac{3}{16}$ $B=\frac{1}{2}$ CEN. ARM HEAD
2- STY. 101 $A=\frac{5}{8}$ $B=\frac{9}{16}$ ARM S. CL. BOLT
2- STY. 204 $A=\frac{5}{8}$ $B=\frac{3}{16}$ $D=1\frac{3}{4}$ ARM CL. BOLT
1- STY. 204 $A=\frac{13}{16}$ $B=\frac{1}{8}$ $D=1\frac{1}{4}$ CLAMP BOLT
1- CENTRE A52
1- CENTRE ADJUSTING WORM A53
1- CENTRE ADJUSTING WORM BUSHING A193- COUNTERBORE FOR SCREWS
1- CENTRE ADJUSTING WORM HEAD A194- DRILL FOR #2 TAPER PIN- C.H.
1- ARM SUPPORT CLAMP BOLT (LONG) A1338-A
1- ARM SUPPORT CLAMP BOLT (SHORT) A1338-B
1- CENTRE ARM HEAD CLAMPING PLATE A2351
1- CENTRE ARM BUSHING B 52-A
1- CENTRE CLAMP BOLT $\frac{S.P.15}{10}$
1- CLAMP PLATE SPRING WASHER $\frac{S.P.201}{26}$
1- CENTRE CLAMP NUT BUSHING $\frac{S.P.119}{6}$ SEE SKETCH

CENTRE ARM HEAD
C.I. A 2313
MADE ON MOULDING MACHINE

FIXTURE FOR CHUCKING # 12247
FIXTURE FOR FACING HUBS # 12248
JIG FOR DRILLING # 12249
TOOLS FOR DRILLING (SEE LIST)
JIG FOR DRILLING ADJ. BUSH. SCR. HOLES # 12250

JIG FOR DRILLING PIN HOLES # 12251
JIG FOR DRILLING PIN HOLE TO LOCATE BUSHING # 12252
CUTTERS FOR MILLING ARM BRACE SEAT # 12253 # 12254
ARBOR FOR SPLITTING # 12235
GAUGE FOR TESTING CENTRE DISTANCE # 12255

SCALE $\frac{1}{2}$ SIZE



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TIME | A2313 | LOT

$A1\frac{1}{2}$, A2, AA2, $B1\frac{1}{2}$, B2, BB2, BY1, BY2, B1, AA1, $AA1\frac{1}{2}$, BB1, $BB1\frac{1}{2}$

CENTRE ARM HEAD (COMPLETE)

DATE JUNE 18 1917 J.K. EX. A.H.C.

BROWN & SHARPE MFG. CO.,
PROVIDENCE, R.I.

A2313 | B.P.G. | VPB

XIII

PLATE XIII

CENTER ARM HEAD

Plate XIII is in some respects similar to Plate IX. In reading this plate, the machinist should first strive to get a general picture of the piece well fixed in his mind. As an aid to this, he will first note that the work, a center arm head, consists of two principal hubs separated by a web or shank to give a center-to-center distance of $7\frac{1}{4}$ inches. The upper hub is simple, having as it does a plain hole through its length and a binder boss on its upper side to be drilled, tapped, and counterbored for a binder bolt. The lower hub, however, is well surrounded by projecting parts which, as they carry several holes and other finished surfaces, decidedly present difficulties to the reader. He will do well to take up each hole as shown in the end view and study each as a single hole, getting its position located in each view.

The larger hole, it will be noted, passes entirely through the main lower hub. The hole placed slightly above this hole and to the right hand of the end view can, by studying the front view, be seen to pass entirely through its hub from end to end. The upper hole of the three shown to the left of the main lower hole will be found to be placed on a center line with the one just noted. A small cross-section view just above, lettered "section *A–B*," aids the reader in clearing up the details of this hole and the two similar lower holes; he should carefully note where the section line *A–B* is drawn on the end view. A study of the front view and of the section view shows that the upper of the three holes passes entirely through the casting from end to end. A study of the two lower holes in the end view shows that they break into each other. Their location in the front view and in the small section view indicates that, while the hole farthest to the left passes entirely through the casting, the other, which cuts into it, is only $1\frac{1}{4}$ inches deep. Extensions of the centers of these two holes show by dimension figures that their center-to-center distance is $\frac{23}{32}$ inch, and a radius line just below the end view shows that the center of the outer hole is $2\frac{7}{8}$-inch radius from the center of the hole in the main lower hub.

Diagonally drawn dotted lines in the end view represent a hole coming in from the front of the casting at an angle of 22

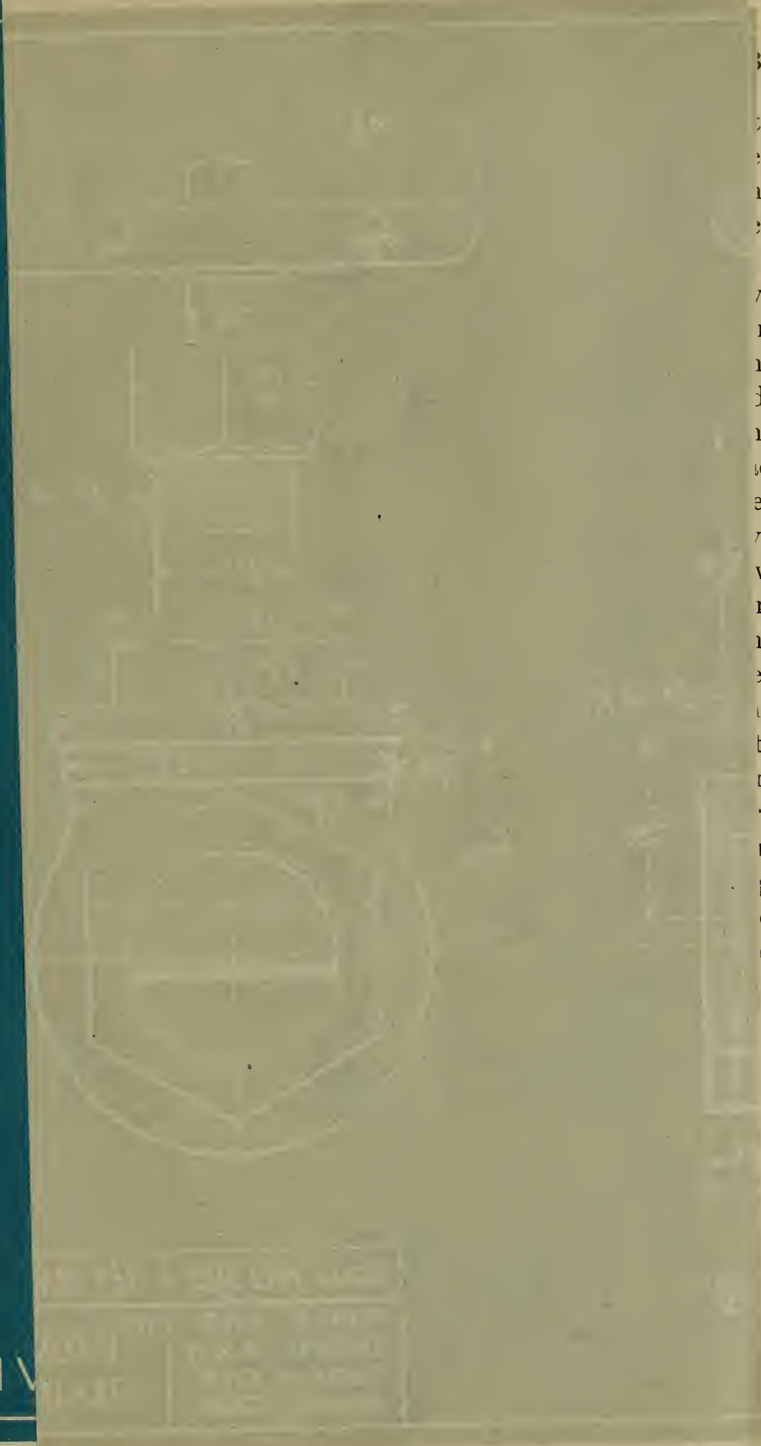
degrees 35 minutes. In the front view this hole and its boss show at the side as a series of full and dotted circles. A lettered note placed on the end view at the right of the vertical center line of the view states that an oil hole is to be drilled. Following carefully the lines which represent the oil hole, the reader will find that it is to be drilled at an angle of $17\frac{1}{2}$ degrees with the center line of a similar $\frac{3}{16}$-inch hole showing through the lower side of the main hub hole. Further examination of the end view draws attention to two small circles at the sides of one of the $\frac{7}{8}$-inch holes. A study of the small section view shows these circles to represent holes drilled, tapped, and counterbored for screws *H* having a $\frac{3}{8}$-inch filister head. A radius arc drawn from the hole beside which these screw holes are placed shows that their centers are placed at $\frac{9}{16}$-inch radius. Other screw holes, oil holes, and pin holes can easily be located by a study of the views. In reading a blueprint such as this, especial care must be used in locating all center lines, radius lines, extension lines, dimension lines, and lines showing angles.

PLATE XIV

BRASS GLOBE VALVE

Plate XIV shows a $1\frac{1}{2}$-inch brass globe valve and the original blueprint is made to full-size scale. Two views only are given. The front view shows the valve sectioned as if cut down through and on the center line, thus clearly giving an inside view of the valve. The end view gives an outline of the valve and is in a sense a picture of the valve. The arrangement of the cross-section lines in the front view indicates that the sectioned metal parts of the valve are, with the exception of the cast-iron handwheel, brass throughout. By means of the outline view and the section, the draftsman has not only shown all the necessary dimensions of the valve as an assembly but has also shown those of each detail so well that the machinist can work it out. While it is not general practice in shops to have the workman work from assembly blueprints, it may well be done when a shop is building a standard article. As there are no finish lines nor *f* marks, the workman would have to decide for himself what surfaces should be finished, if given this drawing to work from.

The several parts of the valve as shown on the blueprint are



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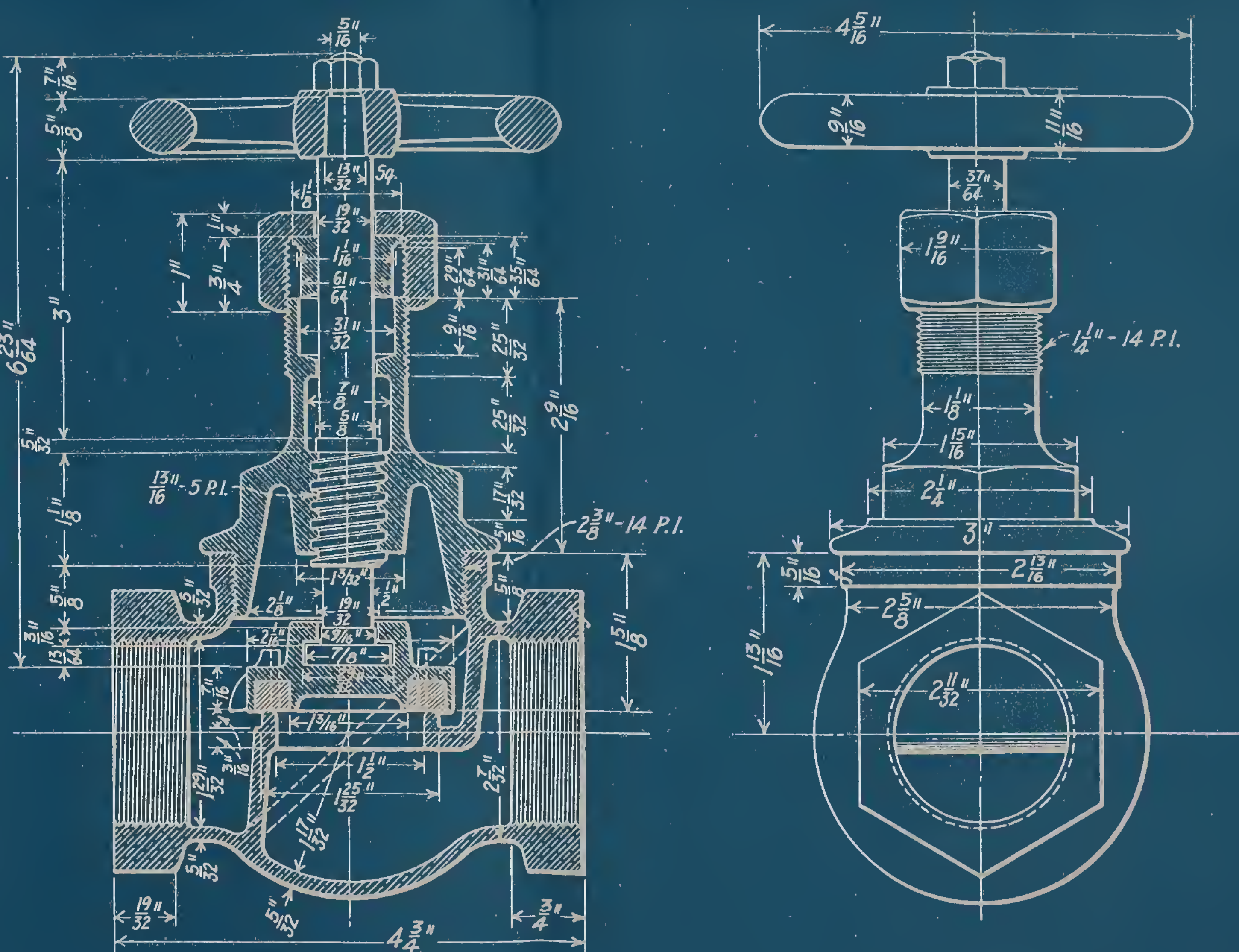

BORE GUIDES 2 3/32"

SCALE *FULL SIZE*	1 1/2" BRASS GLOBE VALVE
DRAWN BY F.P.R. TRACED BY B.X.B CHECKED BY F.P.R. APPROVED O.R.K.	THE PRATT & CADY CO. INC HARTFORD, CONN.

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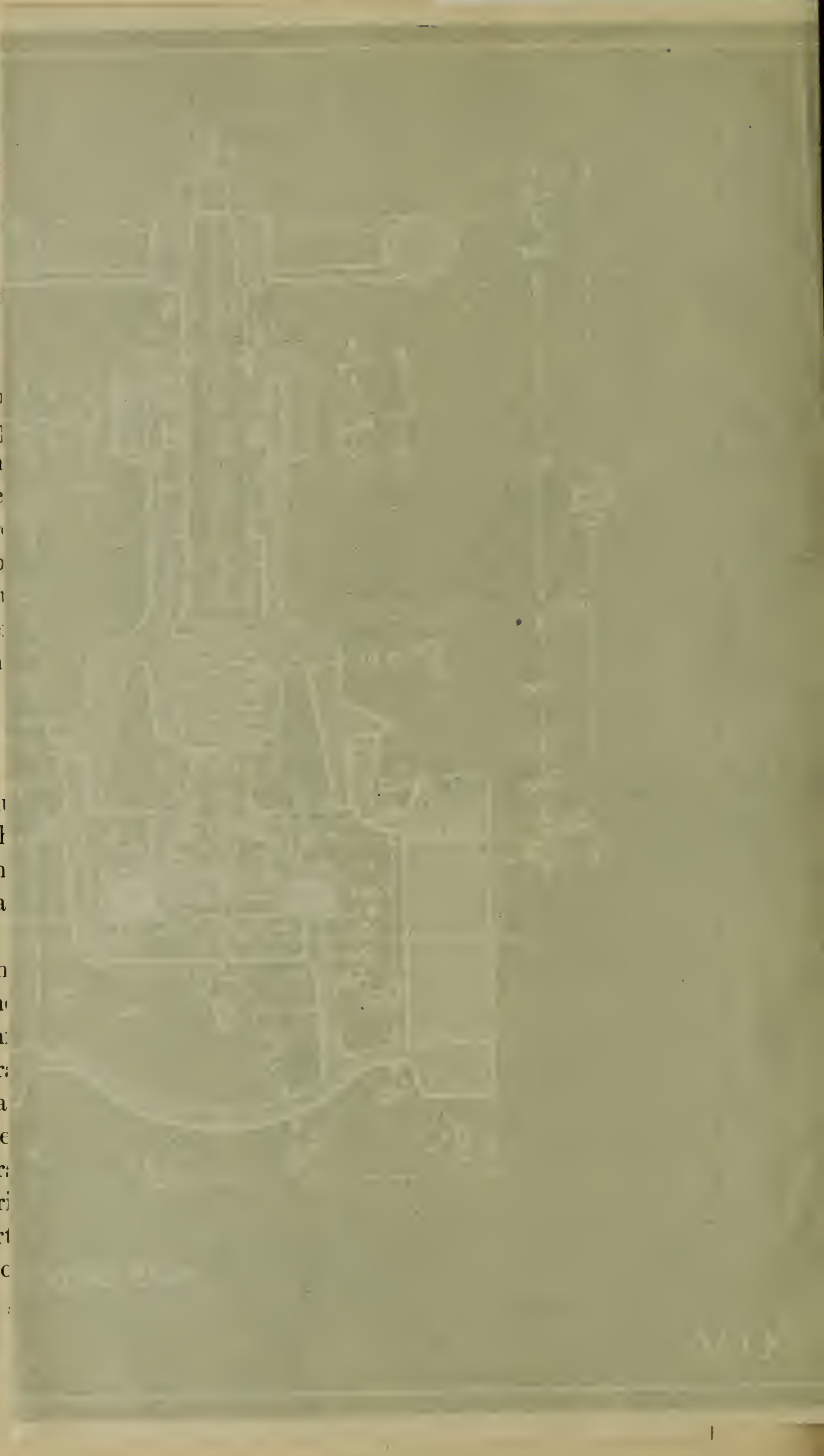

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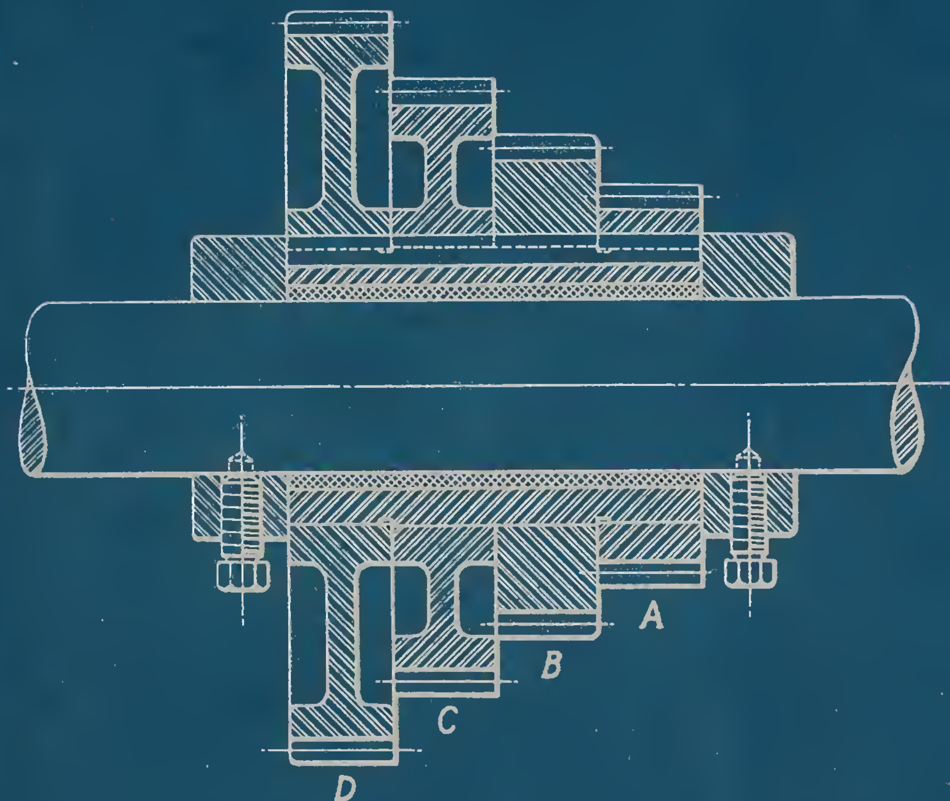

SIZE OF MACH.		NO. OF TEETH AND PITCH	OUTSIDE DIA.	WIDTH OF FACE	PART NO.
2	A	33 T. 8 P.	4.375	$1\frac{1}{8}$"	16810
	B	40 T. 8 P.	5.250	$1\frac{1}{8}$"	13625
	C	50 T. 8 P.	6.500	$1\frac{1}{8}$"	13606
	D	63 T. 8 P.	8.125	$1\frac{1}{8}$"	16808
3	A	31 T. 7 P.	4.714	$1\frac{1}{4}$"	16769
	B	39 T. 7 P.	5.857	$1\frac{1}{4}$"	10849
	C	48 T. 7 P.	7.142	$1\frac{1}{4}$"	12666
	D	60 T. 7 P.	8.857	$1\frac{1}{4}$"	16767
4	A	30 T. 6 P.	5.333	$1\frac{3}{8}$"	16898
	B	38 T. 6 P.	6.666	$1\frac{3}{8}$"	11448
	C	47 T. 6 P.	8.1666	$1\frac{3}{8}$"	11457
	D	58 T. 6 P.	10.000	$1\frac{3}{8}$"	16891
5	A	29 T. 5 P.	6.200	$1\frac{1}{2}$"	16904
	B	35 T. 5 P.	7.400	$1\frac{1}{2}$"	12160
	C	44 T. 5 P.	9.200	$1\frac{1}{2}$"	12158
	D	55 T. 5 P.	11.400	$1\frac{1}{2}$"	16902

PART NAME *DRAWING, ASSEMBLED CONE GEARS*

MACHINE NAME

USED ON *2-3-4-5-PA. UA- 2-3-4-VA. 2-UH & PH- 3-PH*

DRAWN BY *G.W.*

DATE ~~FEB. 25. 09~~ *MAY 25, 10.*

CHECKED BY *S.E.*

APPROVED BY

THE CINCINNATI MILLING MACHINE CO.
CINCINNATI, OHIO.

AMOUNT

SHOP ORDER

NO. WANTED

MATERIAL

PART NUMBER 15713

REMARKS

SUPERSEDES

SUPERSEDED BY

XV

the valve body, consisting of a globular shaped casting with threaded hexagon ends into which, on its upper side, is screwed the valve cover casting with a threaded bearing for the long spindle; and an upper part, consisting of a stuffing box for the wick packing. At the extreme upper end of the stuffing box are a small circular gland and a gland nut to force it along the valve spindle to compress the wick packing into the stuffing chamber. The valve spindle has on its top end a squared taper end to fit the cast-iron handwheel and a threaded hexagon nut to hold the handwheel in place. Toward its lower end an enlarged part of the valve spindle is threaded with a rather coarse-pitch Acme thread to fit the threaded bearing in the valve cap. The extreme lower end of the valve spindle is enlarged and finished to carry the valve disc which seats itself on the valve body seat to close the flow through the valve body from end to end. The disc, or upper, seat moves up and down in narrow guides, as shown in the front section view, and a lettered note placed just below this view states that these guides are to be bored $2\frac{3}{32}$ inches in diameter. The disc has in its lower, or seat, side a circular recess, $1\frac{15}{16}$ inches outside diameter by $1\frac{3}{16}$ inches inside diameter, for a fiber, leather, asbestos, or other seat ring. Two dotted lines about $\frac{3}{16}$ inch apart drawn diagonally across the inside of the valve body, as shown in the front view, represent a diaphragm rib. This is an interesting blueprint to read, as it is necessary to locate carefully all the *extension* lines to learn which *working* lines they extend. Care must also be taken to determine which lines many of the arrow points exactly touch.

PLATE XV

ASSEMBLED CONE GEARS

Plate XV illustrates a method of using an assembly drawing for shop purposes. The view shows a cone of four gears in section on a shaft. The arrangement of the cross-section lines indicates that the gears are made of machinery steel. As shown, the whole cone of gears is mounted on a steel sleeve which, in turn, runs on a composition sleeve. The whole combination is held in position on the shaft by steel collars having hexagon-head set screws. As is customary in such section views, the shaft is not shown sectioned.

Its ends, however, are shown as if broken off and the arrangement of the section lines at the break indicates that the shaft is of steel.

Immediately below each gear, as shown in the view, are placed the letters *A–B–C–D*. The first column of a lettered table placed in the upper right-hand corner shows that similar cones of gears are used on machines, size 2, 3, 4, and 5. The next column gives the number of teeth and the pitch of the teeth required in the gears *A–B–C–D* for the various sizes of machines. The remaining columns of the table give the outside diameter of each gear and its width of face. From this single section view, supplemented by the lettered table, the machinist should be able to get all the essential information for making these gears, with the exception of the hole diameter, which is not given. The two smaller cone gears are shown as if made from a plain steel blank, while the two larger gears plainly show that they have a distinct hub and rim with a thin web connection.

PLATE XVI

FACE GEAR

The two views of a special face gear shown in Plate XVI are half size in the original blueprint. The term "face gear" indicates that the piece represented is the large driving gear on the main spindle of the machine. While no finish *f* marks are found on the working lines of this blueprint, the average machinist would know that the outer diameter, the ends of the hubs, the holes through the gear, and the sides of the rim should be carefully and well finished. In addition to this, a lettered note at the upper right of the front view states that the surfaces indicated by the arrow points are rough turned. The title plate informs us that one is required and that the material is cast iron, which is also indicated by the arrangement of the cross-section lines in the front view.

The view looking toward the end of the gear hub shows that the upper small hub has a short supporting flange and that on its lower edge the upper hub is counterweighted. A lettered note placed just at the left of the front view tells us that the hole in the hub is keyseated $\frac{13}{32}$ inch deep and $\frac{5}{8}$ inch wide and that the key is dovetailed and drives into place. Both views show the key

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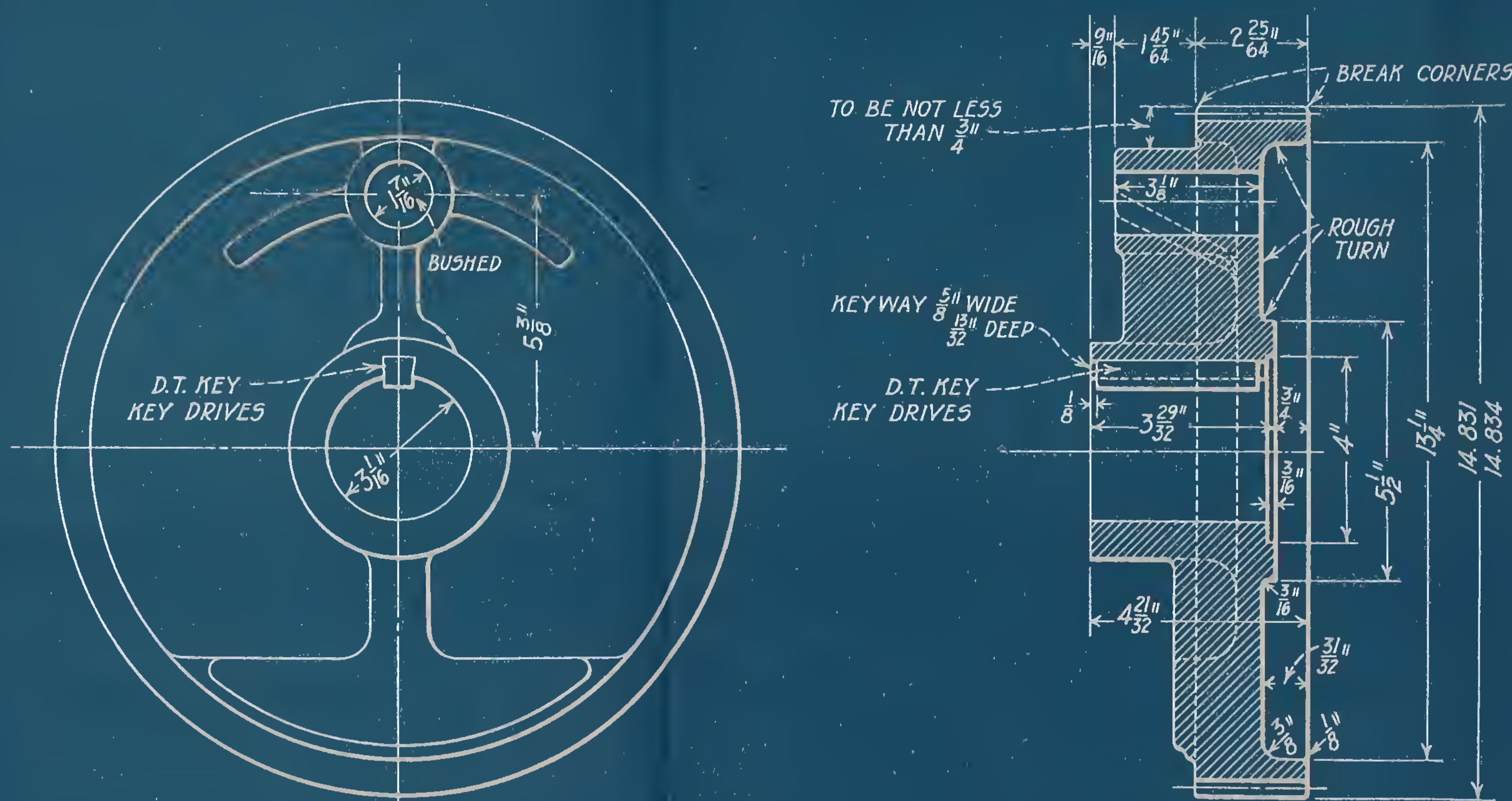

HALF SIZE

PART NAME	GEAR, FACE	MACHINE NAME		
USED ON				
DRAWN BY C.F.S.	DATE AUG. 8-10		NUMBER WANTED & MATERIAL	1- C.I.
CHECKED BY P.M.	THE CINCINNATI MILLING MACHINE CO. CINCINNATI, OHIO.	AMOUNT	SHOP ORDER	PART NUMBER 19711
APPROV'D BY				

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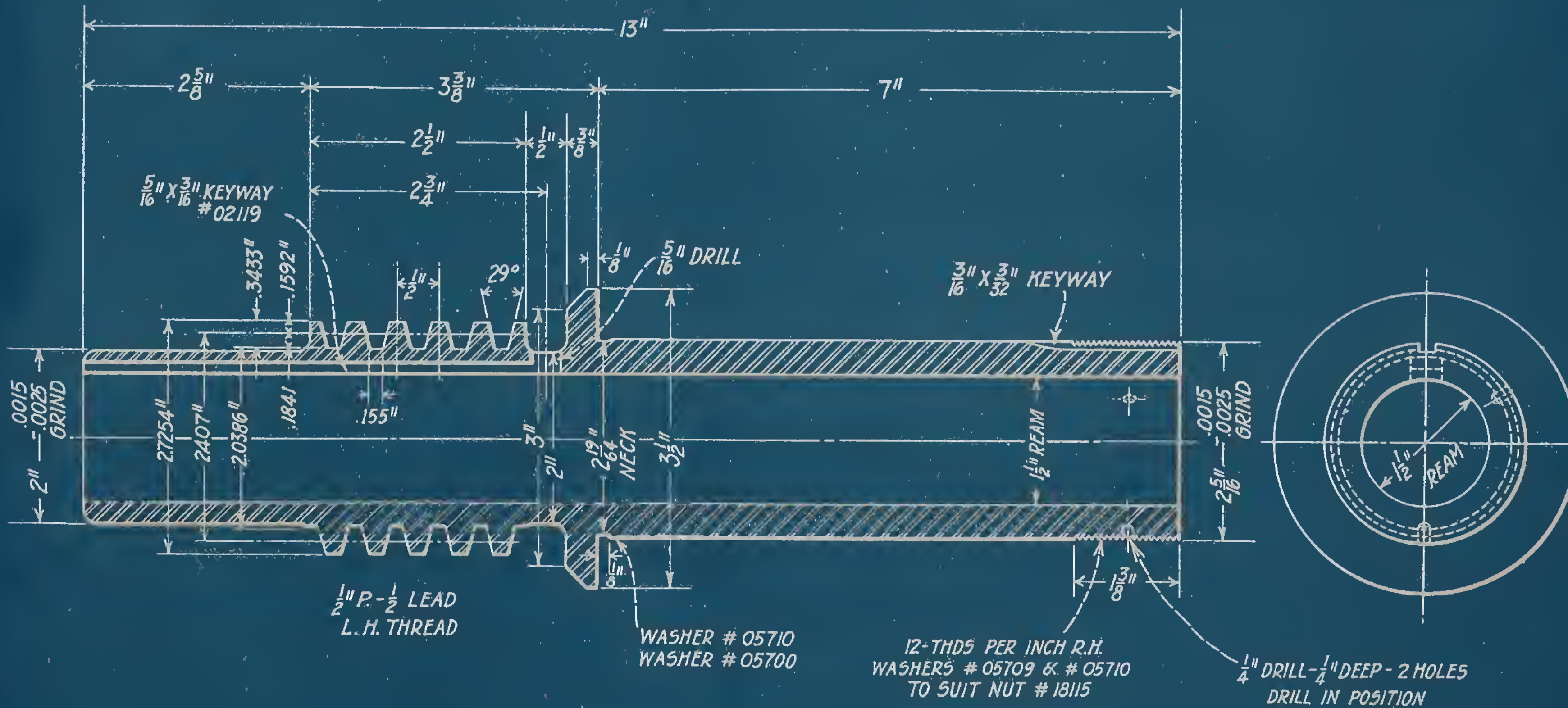
NAME OF PIECE	AMT. REQ.	NAME OF MACHINE	PIECE NO.
DOWN FEED WORM-R.H. HEAD-	ONE	5-FT BORING MILL	14063



F. A. O.

PIECE NO.
14063

GROUP NO.	TRACED BY	DATE	CHECKED	THE CINCINNATI PLANER CO.	MATERIAL	USE PATT. NO.	SIZE	LENGTH
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in place. Another important lettered note states that there are eighty-seven teeth milled into the outer face of the piece and that they are to be six pitch. The workman should especially note that the over-all diameter is to be held to definite limits of tolerance.

PLATE XVII

DOWN-FEED WORM

The upper title plate states that the piece shown in Plate XVII is a down-feed worm for a 5-foot boring mill. One is required and the lower title plate gives the material as machinery steel cut from $3\frac{3}{4}$-inch rod $13\frac{1}{8}$ inches long, rough dimensions. Two views are given, with the front view sectioned to indicate steel. All dimensions are given on the front view. The end view is sufficient to show that in general the piece has circular outlines. The end view also shows the shape of the two keyways and, while no direct dimensions are given, this view shows the general position of the holes mentioned in the lettered note, "$\frac{1}{4}''$ drill–$\frac{1}{4}''$ deep–2 holes–drill in position".

In considering this piece of work, the machinist is, of course, first concerned with the reamed $1\frac{1}{2}$-inch hole through its length. After this hole is finished ready for the mandrel, he should carefully read all the notes and other lettered directions before beginning to square up and turn the piece. He should especially observe what surfaces are to be ground and give careful attention to the finished dimensions. He will note that certain dimensions have a small limiting tolerance given in thousandths of an inch. He should also note that, while the fine-pitch thread shown on the right end of the front view is a *right-handed* thread cut to suit a certain nut, the coarse-pitch 29-degree worm thread is to be cut *left-handed.* All dimension lines, figures, and extension lines are very clear and are easily located in reference to their working lines. The lettered notes have clearly defined arrow points to indicate the surfaces to which they refer. Attention is called to the diameter dimension reading "$2\frac{19}{64}$ inches neck". This shows that the piece is to be necked in to this diameter previous to grinding the $2\frac{5}{16}$-inch diameter as a protection to the corner of the grinding wheel. No finish *f* marks are shown, as the piece is finished all over, and this fact has been indicated by the initial letters

F.A.O. placed just below the front view. The $\frac{5}{16}$-inch hole showing just to the left of the flange collar should be drilled before cutting the keyway to give a clearance for the cutting point of the keyseating tool.

PLATE XVIII

SADDLE ADJUSTING LEVER

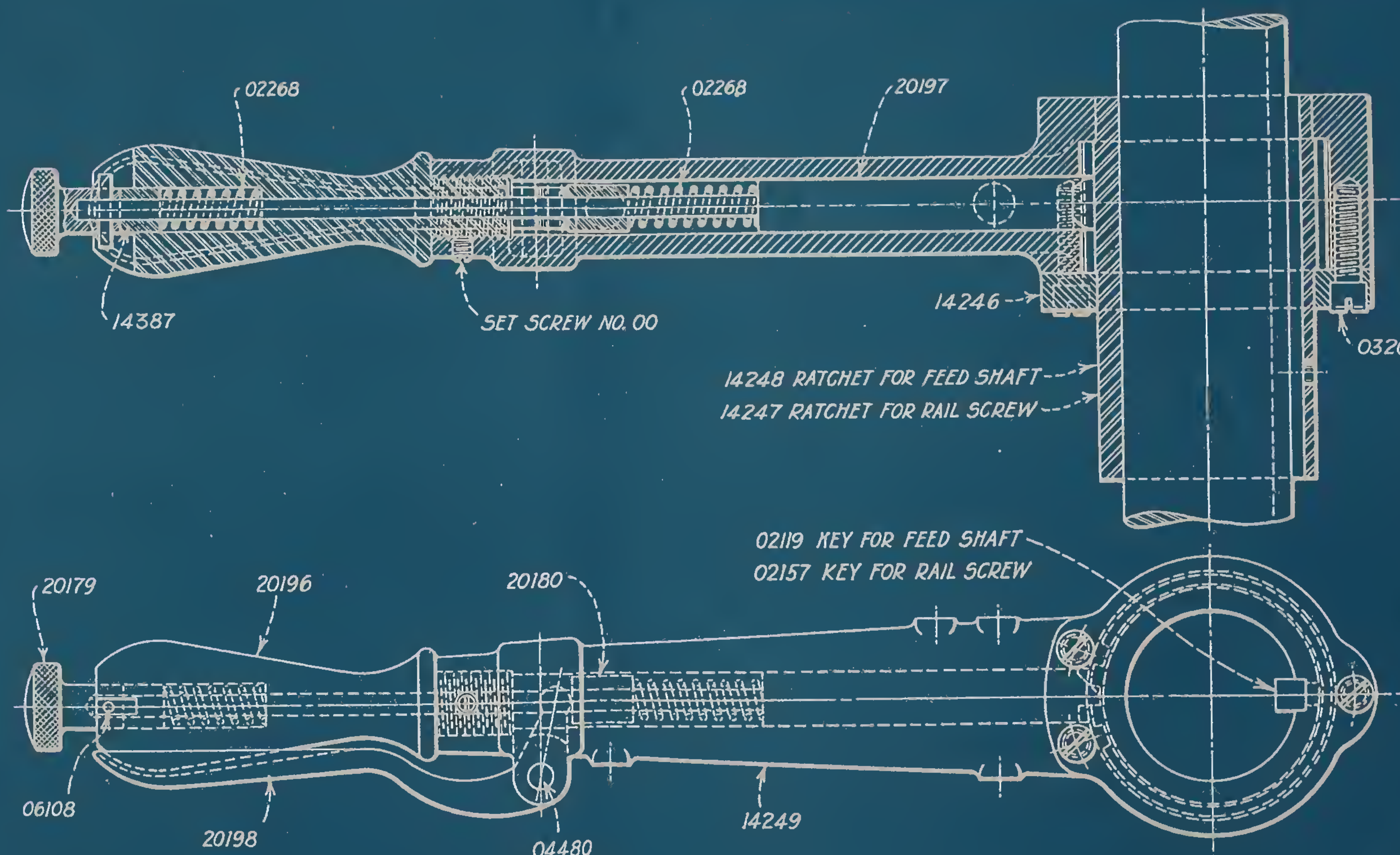
Plate XVIII, an assembly blueprint, is for the use of the setting-up machinist and clearly indicates how the group of parts which make up the saddle adjusting lever are assembled. It will be noted that each pin, cap screw, set screw, spring, lever arm, sleeve, etc., is given a part number and that an arrow point clearly indicates the part referred to. The arrangement of the cross-sectioning lines in the top view clearly indicates the material of each part; for example, they show that the lever arm *#14249* and its hub are cast iron, while the handle screwed into its upper end is of steel. While the shape and position of each part of this mechanism are clearly shown in this blueprint, no dimensions are given, which shows us that, as previously stated, the print is to be used in the shop only by the assembler. The reader in studying this blueprint should consider that he is to assemble the various parts and endeavor to decide in what order they should be assembled: for example, it is clear that *#20197*, *02268*, and *20180* must be placed in position in *#14249* previous to screwing *#20196* into it; also that *#14249* must be placed in position on *#14248* previous to attaching cover plate *#14246*.

PLATE XIX

TOP PULLEY BRACKET

The top title plate informs us that the several views shown in Plate XIX are of a top pulley bracket for a 5-foot boring mill and that two are required. The lower title plate states that the material is cast iron. The views are a front view, a right side view, and a top view, which is in this case projected and positioned just above the right side view. The arrangement of full and dotted lines indicates that the piece consists of a hollow base, or pedestal, having at its upper end a shaft-carrying box, or bearing, which, in turn, has a large grease, or oil, pocket on its upper side.

NAME OF GROUP	AMT. REQ.	NAME OF MACHINE	GROUP NO.
SADDLE ADJUSTING LEVER	4	5-FT BORING MILL	14014



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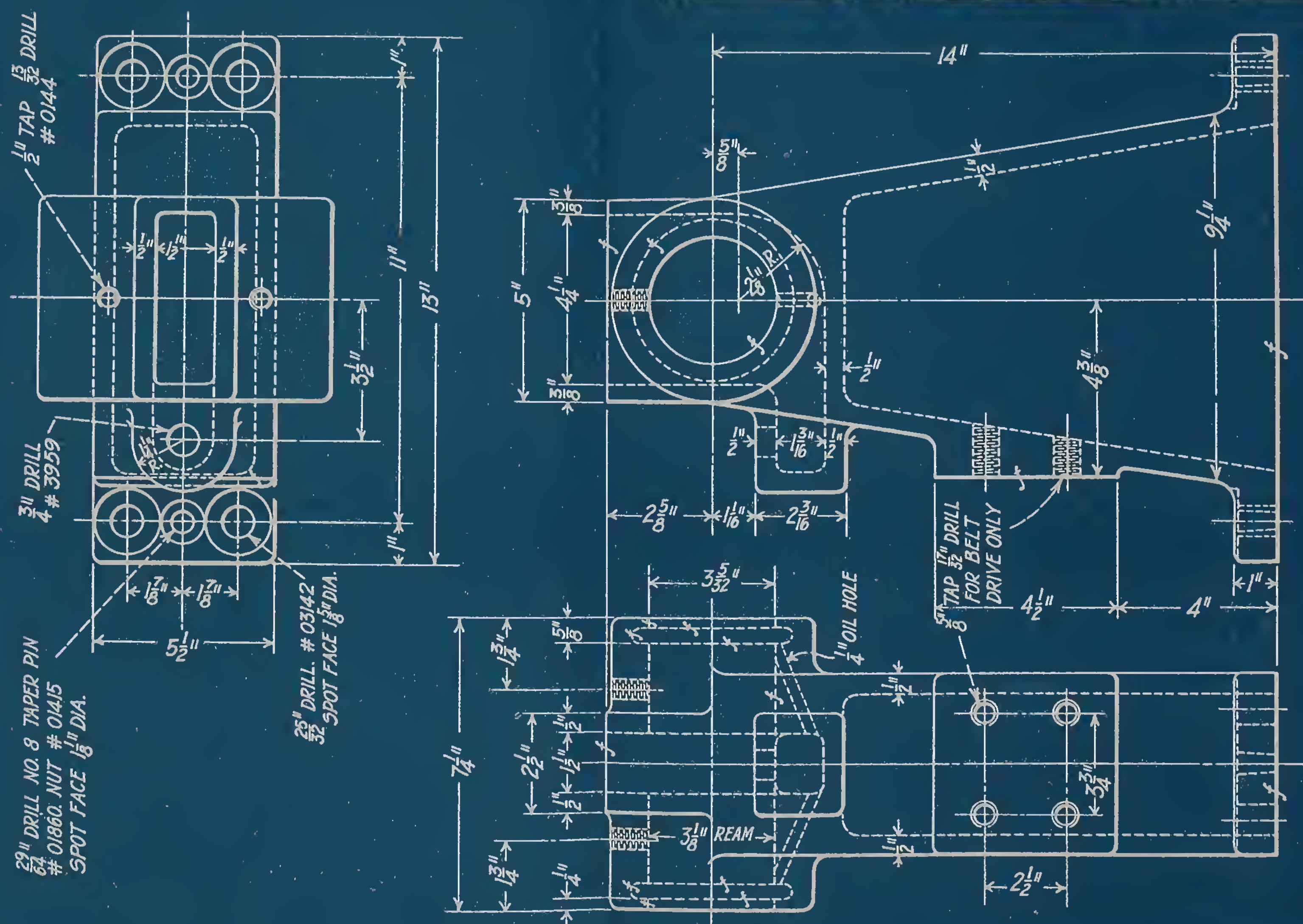
NAME OF PIECE	AMT. REQ.	NAME OF MACHINE	PIECE NO.
TOP PULLEY BRACKET	2	5-FT BORING MILL	14200



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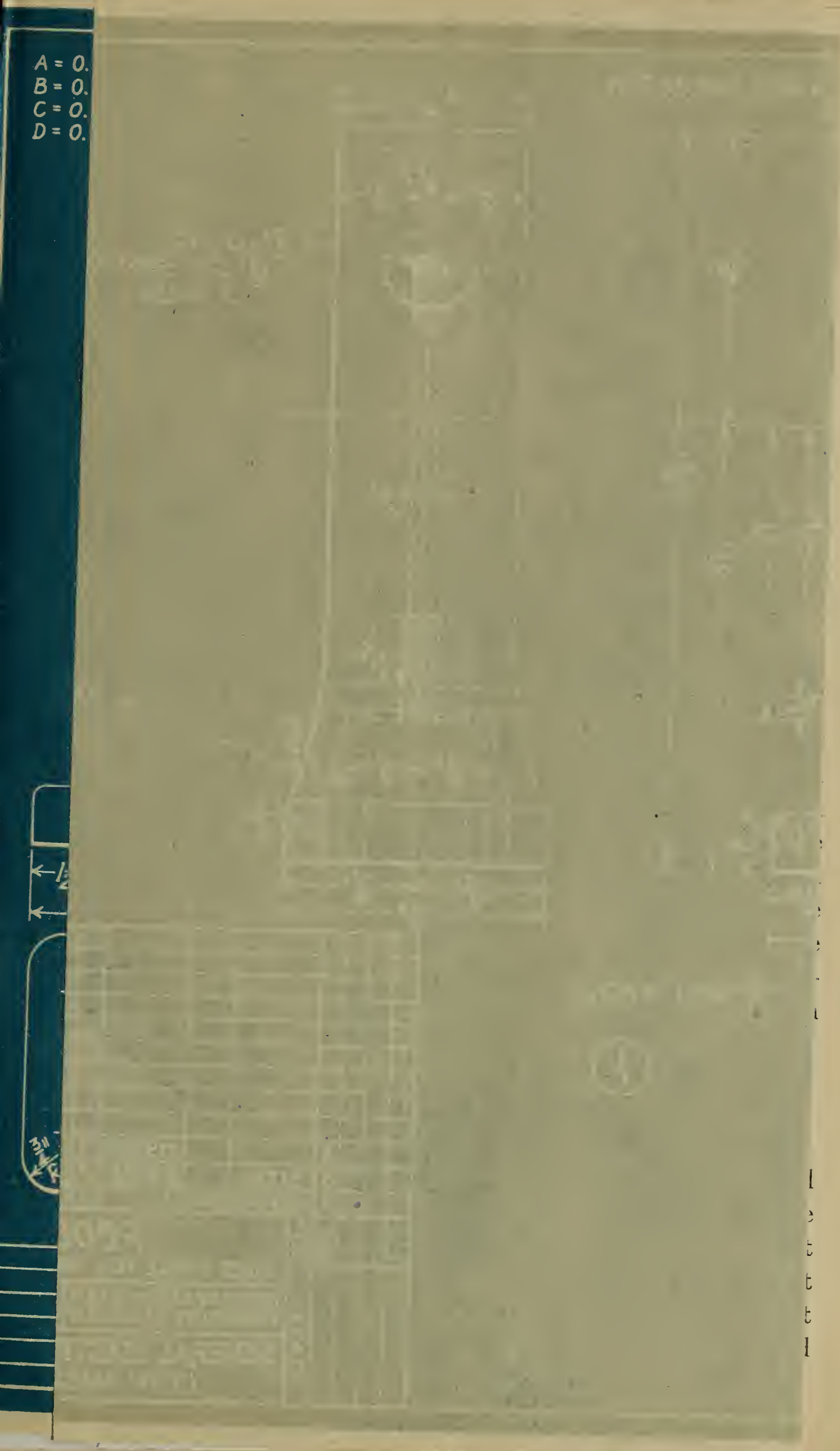
In reading this blueprint, the machinist should observe that many of the dimensions given are for the use of the pattern maker and are of no especial concern to him. The pattern maker, on the other hand, is concerned with all the dimensions as he must add sufficient stock to every surface marked with an *f* to allow excess metal for the machinist's purposes. As an instance of this, take some of the dimensions as given on the front view and the right side view. We observe that at the extreme right hand of the side view a dimension of 14 inches is given from the lower line, or base, of the pedestal bracket to the center line of the box. While this is a dimension for the machinist in particular, the pattern maker must also note that the base surface is to be finished and make the dimension enough longer than 14 inches so that the machinist will have metal stock sufficient to allow him to finish the base surface and still have the correct dimension. Also, in considering the shaft hole given as $3\frac{1}{8}$ inches ream, the pattern maker must make his core prints and core boxes enough less than $3\frac{1}{8}$ inches in diameter to allow stock for machining the hole to the specified size. The pattern maker only is concerned with the dimension $\frac{1}{2}$ inch given for the wall thickness of the hollow pedestal and that of $9\frac{1}{4}$ inches given at the bottom of the side view for the width of the pedestal. These and many other dimensions are not subjected to any machining. The pattern maker, then, in reading this blueprint will carefully consider each and every working line, whether drawn full to represent a visible outside surface or drawn dotted to represent an invisible inside surface, in order to give himself a clear mental picture of the construction not only of the outer outlines of the piece but also of all the interior outlines. When the pattern maker has this clear mental picture of the piece, he can then readily trace the dimensions of all parts of his construction by following the extension lines.

If the pattern maker has fully understood the views up to this point he clearly sees: (a) that they represent a ring oiling pedestal bracket with the base cored out to leave walls $\frac{1}{2}$ inch thick, the cored portion to extend up from the base line of the bracket to within $\frac{1}{2}$ inch of the bottom surface of the cored oil chamber; (b) that the cored oil chamber is $4\frac{1}{4}$ inches in length in a direction across the shaft bearing and $1\frac{1}{2}$ inches in width along the shaft

hole, and that the oil chamber extends out toward the front of the bracket into a rounded-end projection, or lug; (c) that he must provide a loose pad on the front of the pedestal, as shown, "for belt drive only"; and (d) that the bottom surface of the bracket, the entire hole through the bracket box, the upper surfaces of the oil pocket, and the front face of the bracket pad are to be machined as indicated by finish *f* marks, and that excess stock for machining off must be allowed on such surfaces.

The machinist in reading the views should carefully note which surfaces are marked with the finish mark for machining. Starting at the pedestal base, as shown in the front and the side views, he will observe that its lower surface is to be machined and that certain holes are to pass through it. A study of the top view and its lettered notes shows that there are to be three holes through the base in each of its ends. Two of each three are drilled for holding-down bolts and one for No. 8 locating taper pins. The holding-down bolt holes are to be spot faced for the heads of the bolts.

Returning to a study of the front and side views, the machinist notes that the front surface of the pad is to be machined. This surface, as shown in the side view, is $4\frac{3}{8}$ inches from the vertical center line. Four $\frac{5}{8}$-inch tapped holes are to be drilled into the face of the pad $3\frac{3}{4}$ inches apart along the horizontal distance and $2\frac{1}{2}$ inches apart in the vertical dimension. Before machining the shaft bearing shown at the upper part of the front and the side views, the machinist should note: (a) that the bearing proper extends in length from the inner edge of a narrow circular oil-collecting pocket to the inner edge of a similar opposite circular oil-collecting pocket and that this bearing surface is bored and reamed to a diameter of $3\frac{1}{8}$ inches; (b) that outside of the circular oil-collecting pockets, the hole diameter is increased to $3\frac{5}{32}$ inches; (c) that while the circular oil-collecting pockets are marked *f* and are therefore to be machined, no dimensions are given, this indicating that they are simply machined to remove the original scale and to make them truly circular; and (d) that a large central oil-containing chamber is provided for an oil-conveying ring and that two oil-return holes are drilled from the edges of the two circular oil-collecting pockets at an angle which allows them to enter the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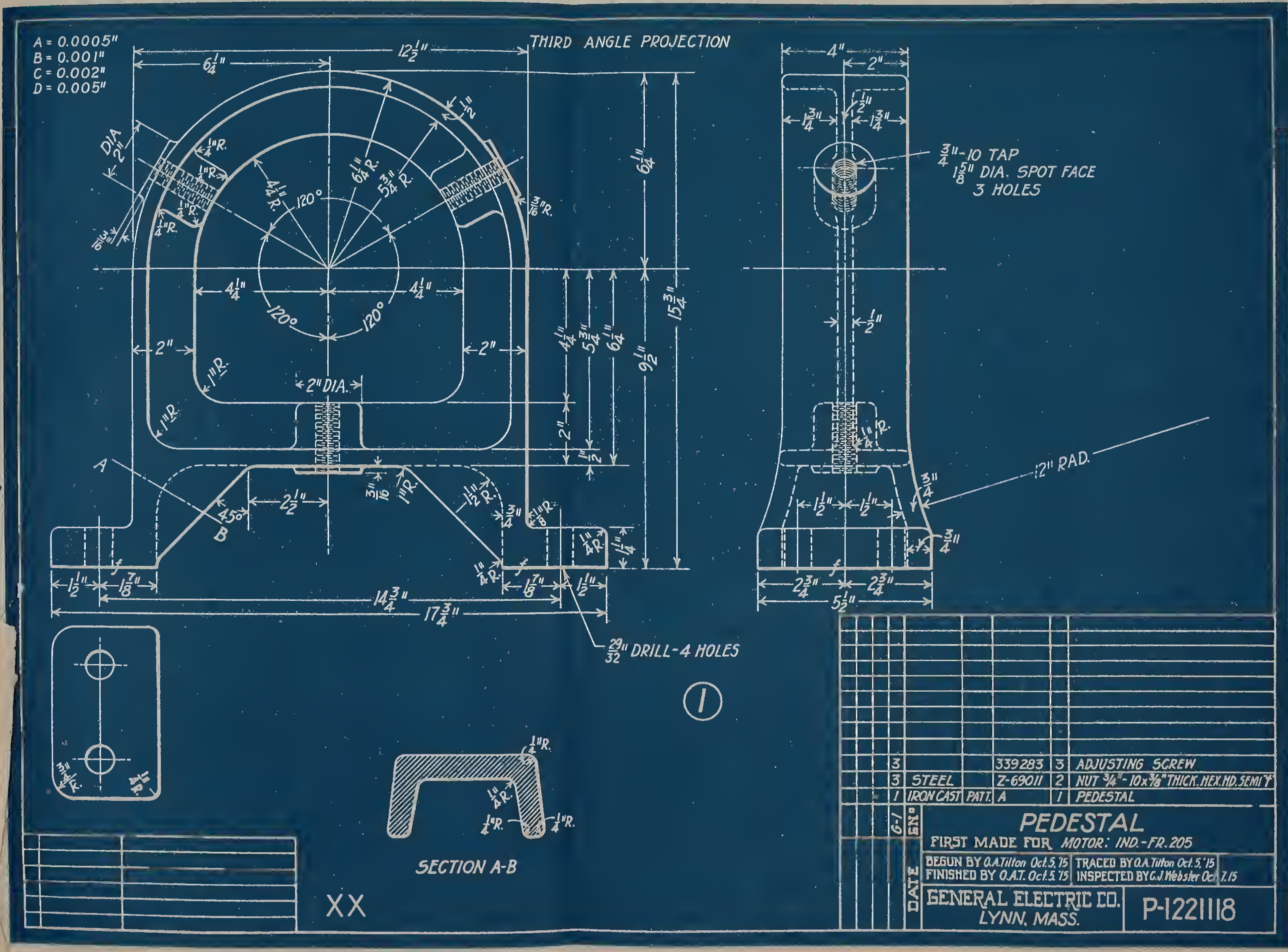

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3 HOLES
12" RAD.
29/32" DRILL-4 HOLES
SECTION A-B
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3 | 339283 | 3 | ADJUSTING SCREW
3 | STEEL | Z-69011 | 2 | NUT 3/4"-10x3/8" THICK. HEX. HD. SEMI'F'
1 | IRON CAST | PATT. A | 1 | PEDESTAL
PEDESTAL
FIRST MADE FOR MOTOR: IND.-FR. 205
BEGUN BY O.A.Tilton Oct. 5, '15
FINISHED BY O.A.T. Oct. 5, '15
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INSPECTED BY G.J.Webster Oct. 7, '15
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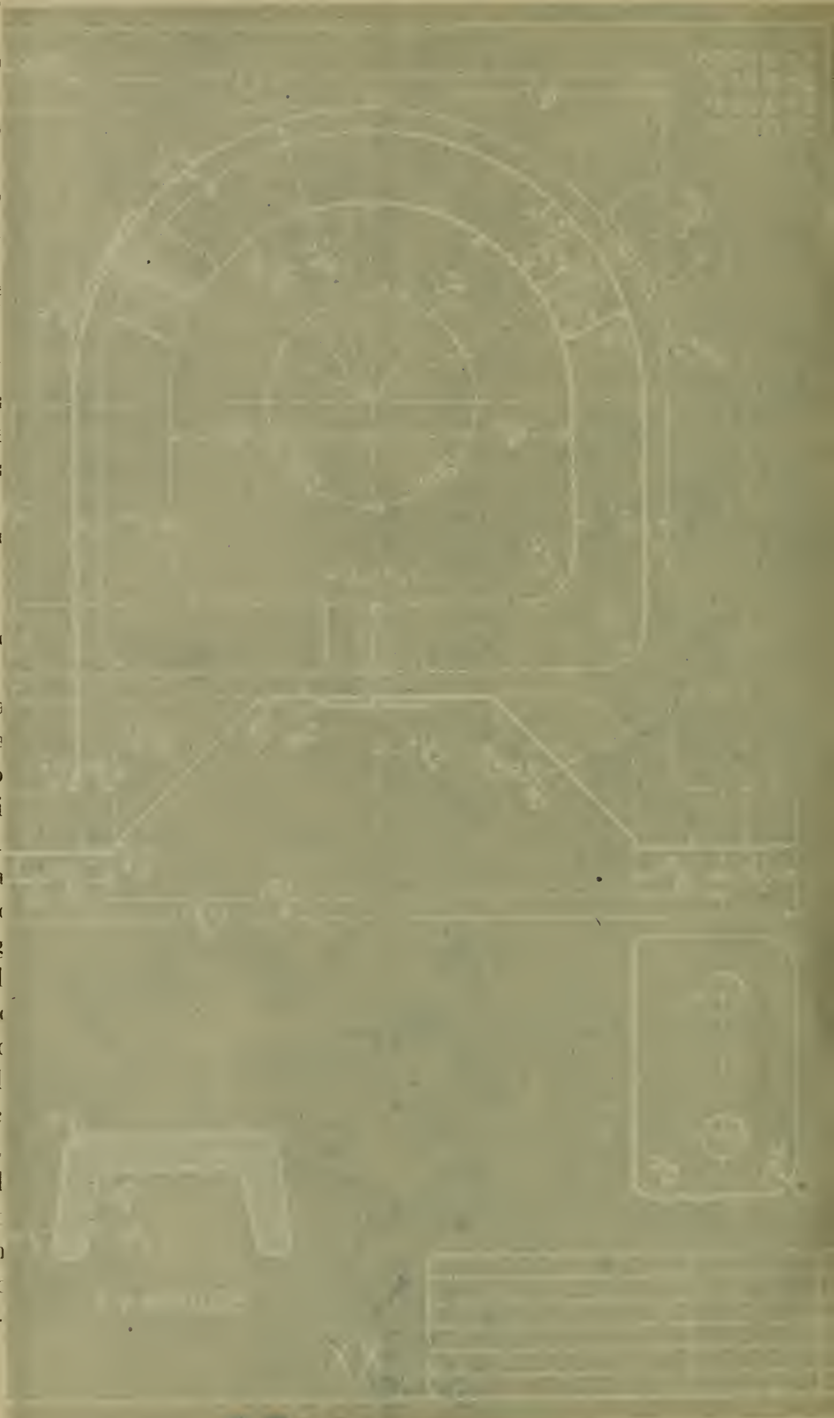

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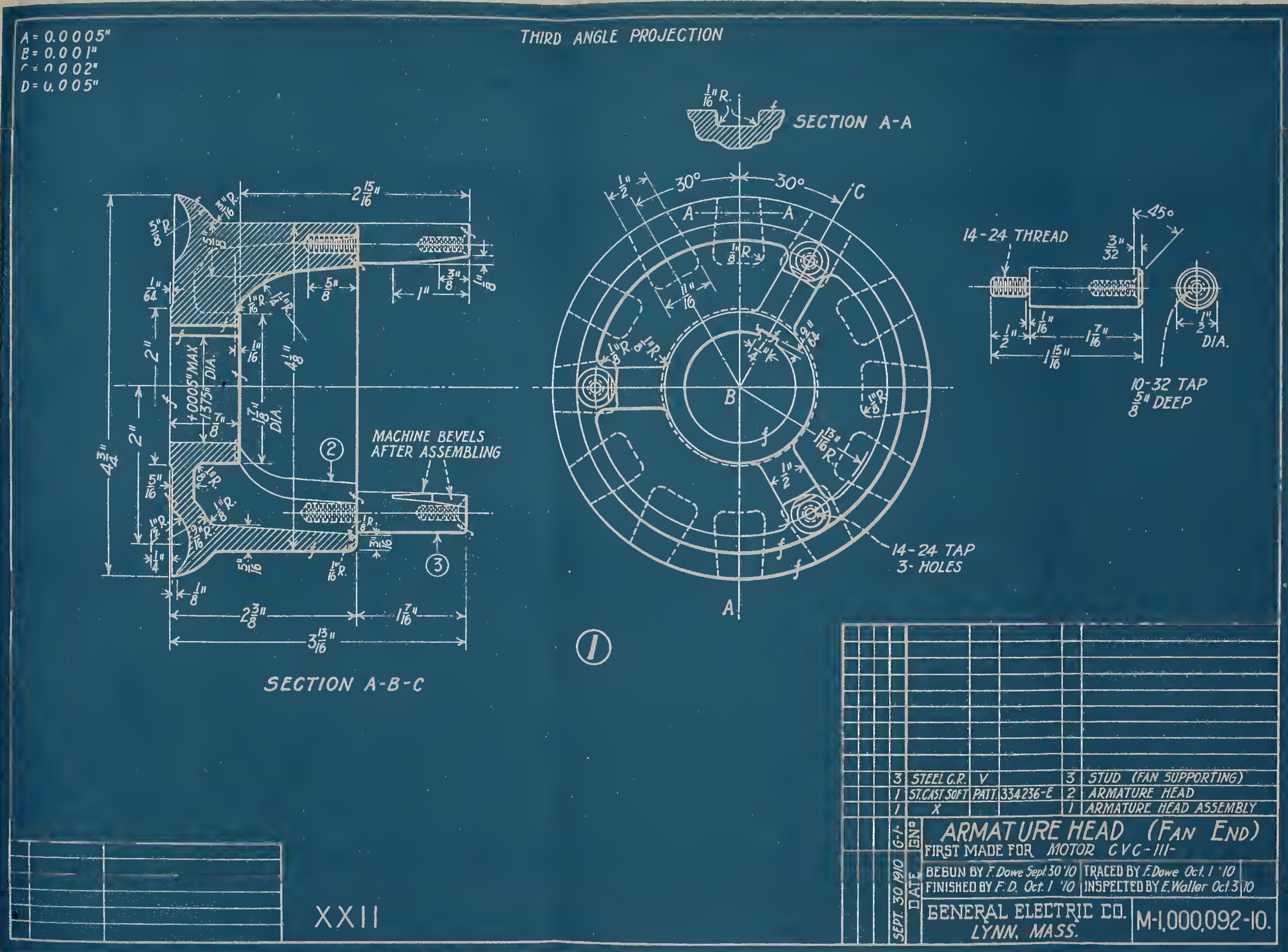
A = 0.0005"
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D = 0.005"
THIRD ANGLE PROJECTION
SECTION A-A
SECTION A-B-C
MACHINE BEVELS AFTER ASSEMBLING
14-24 THREAD
10-32 TAP 5/8" DEEP
14-24 TAP 3- HOLES
1.375" DIA.
+.0005" MAX
3 STEEL G.R. V 3 STUD (FAN SUPPORTING)
1 ST.CAST SOFT PATT. 334236-E 2 ARMATURE HEAD
1 X 1 ARMATURE HEAD ASSEMBLY
ARMATURE HEAD (FAN END)
FIRST MADE FOR MOTOR CVC-111-
BEGUN BY F. Dowe Sept 30 '10
TRACED BY F. Dowe Oct. 1 '10
FINISHED BY F. D. Oct. 1 '10
INSPECTED BY E. Waller Oct 3 '10
SEPT. 30 1910
G-1-
GENERAL ELECTRIC CO.
LYNN, MASS.
M-1,000,092-10.
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central oil-containing chamber, the lettered note stating that these oil holes are $\frac{1}{4}$ inch in diameter. Two threaded holes are shown through the upper shell of the shaft-bearing box and a note attached by a line and an arrow point to the upper view explains that they are to be drilled $\frac{13}{32}$ inch for a $\frac{1}{2}$-inch tap. Finally, the upper surfaces of the oil box are marked *f* to be machined.

PLATE XX

SHAFT-BEARING PEDESTAL

Plate XX shows a shaft-bearing pedestal in which the shaft-bearing box is a separate unit (not shown) which may be supported inside the pedestal. As the shaft-bearing box would be held exactly central with the frame of the pedestal, many of the working lines of the left side view are drawn around the center line, or axis, and several of the dimensions are figured as a radius from a common center. The views consist of a front, or edge, view, a left side view, and two smaller views, one of which is a section on line *A–B* and the other is placed just below the side view and shows a bottom view of the feet of the pedestal.

Very little machine work is to be done on this piece, merely machining the base supports on their under surface, drilling holes in the feet for four holding-down bolts, and drilling, tapping, and spot facing the three prominent bosses. It will be noted by the machinist that the latter holes are at an angle of 120 degrees with one another. The machinist should also observe that the base supports are to be finished to give their under surface a distance of $9\frac{1}{2}$ inches from the center line, or axis, of the views. Practically all the remaining dimensions are given for the pattern maker's use and are easily located and read.

PLATE XXI

END SHIELD

In reading the front view, the small view, and the right end view of Plate XXI, the reader should clearly see that when he looks at the right end view, he is in fact viewing this *end shield* at its large open end. A study of the front section view shows that the casting essentially consists of a large cup-shaped portion at the right with only a rim bottom. A half rim is attached and

projects to the left and carries a circular hub having a circular hole of two diameters. In this blueprint the machinist, to understand the views, must carefully follow each working line of the drawing, locate each extension line, and note each arrow-pointed line.

All the important finished dimensions are given a limiting tolerance in thousandths of an inch. The rim edge of the large cup shown at the right of the front section view is finished to a 5.250-inch diameter and 0.094-inch depth; and three holes through the rim bottom are also finished. Two of these holes, $4\frac{15}{16}$ inches center to center, are counterbored for fillister-head cap screws, while the third hole, showing at the top of both views $2\frac{1}{4}$ inches up from the center line, is countersunk for riveting. A detail of this is given on the lower side of the blueprint. The circular hub which shows at the left of the front section view is machined on its outer end and a double-diameter hole is finished through it. Four holes are drilled and tapped into the outer face of the hub. A lettered note placed slightly to the left and above the hub gives the necessary information for these holes.

PLATE XXII

ARMATURE HEAD

Plate XXII is a combined assembly and detail blueprint and according to the title plate is made up of 1 armature head assembly, 2 armature head, and 3 stud (fan-supporting), the whole being given the title plate name armature head. The numbers 1, 2, and 3 are clearly shown in the blueprint placed near or on the views. The material of the stud is given in the title plate as cold rolled steel and that of the armature head as soft steel casting. The front view is shown in section on line *A–B–C*. The careful reader will note that section line *A–B–C* follows the vertical center line of the right side view from *A* at its lower edge to *B* at the center axis and then slants to the right and upward, following the center line of one of the three ribs to *C*.

Stud. A study of the front and the end views shows that the studs 3 (also shown at the upper right of the blueprint) are screwed into the three ribs just mentioned, and a lettered note placed on the sectioned front view states that they are machined to a bevel after assembling.

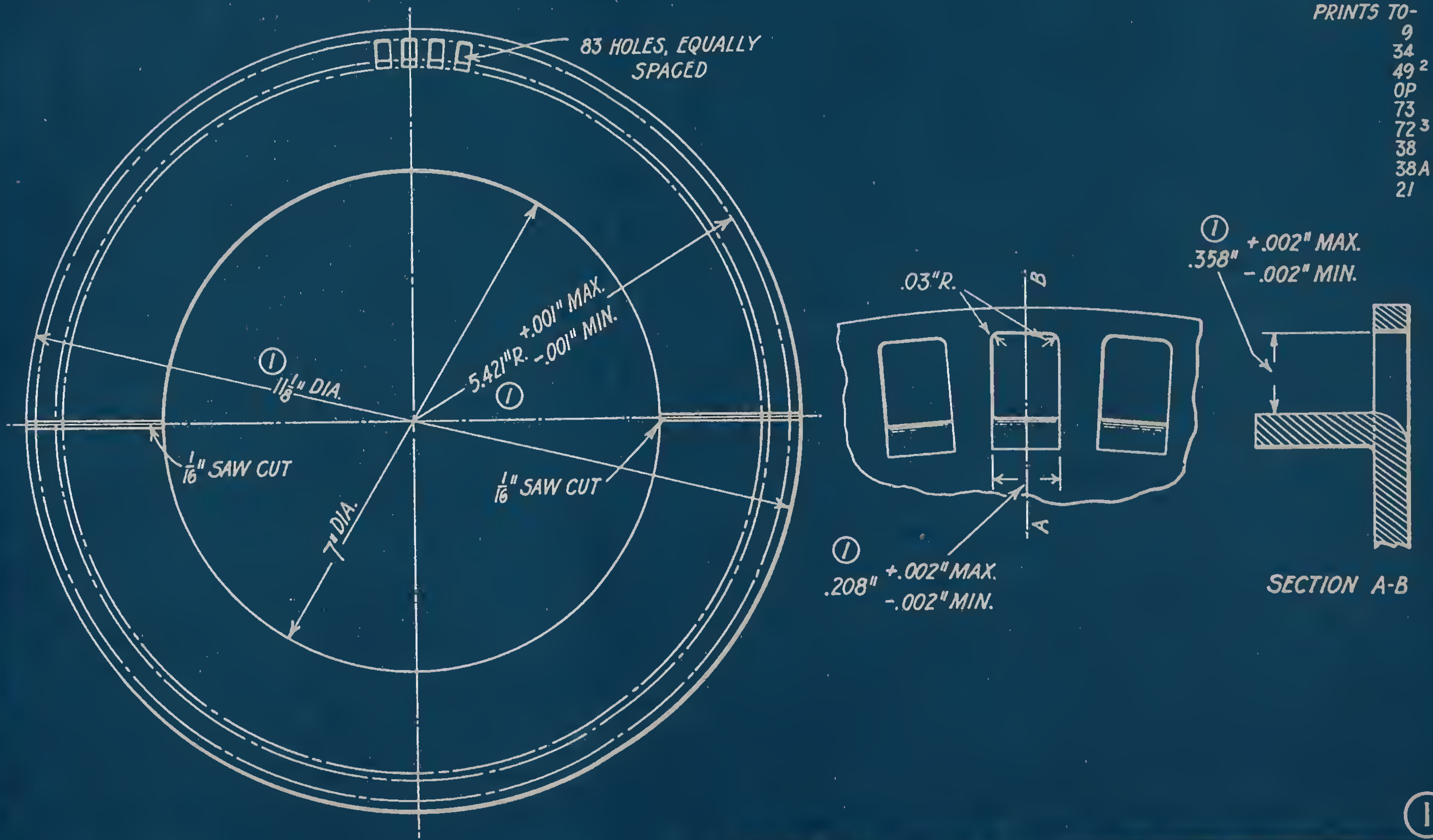
A = 0.0005"
B = 0.001"
C = 0.002"
D = 0.005"

THIRD ANGLE PROJECTION

PUNCHED — PART

COPPER SH. HARD .125" TH. — MATERIAL

PRINTS TO-
9
34
49 2
OP
73
72 3
38
38A
21



FIRST MADE FOR	ARMATURE END RING
MOTOR GEN. SET M.I.C. 3KW-1800-440/125 REG. N- 99438	GENERAL ELECTRIC CO., LYNN, MASS.
DRAWN BY J. Osterberg	DATE OCT. 8-08 A.S. — 343066

C ① FEB. 24 '09
CH'D DATE

XXIII - 1

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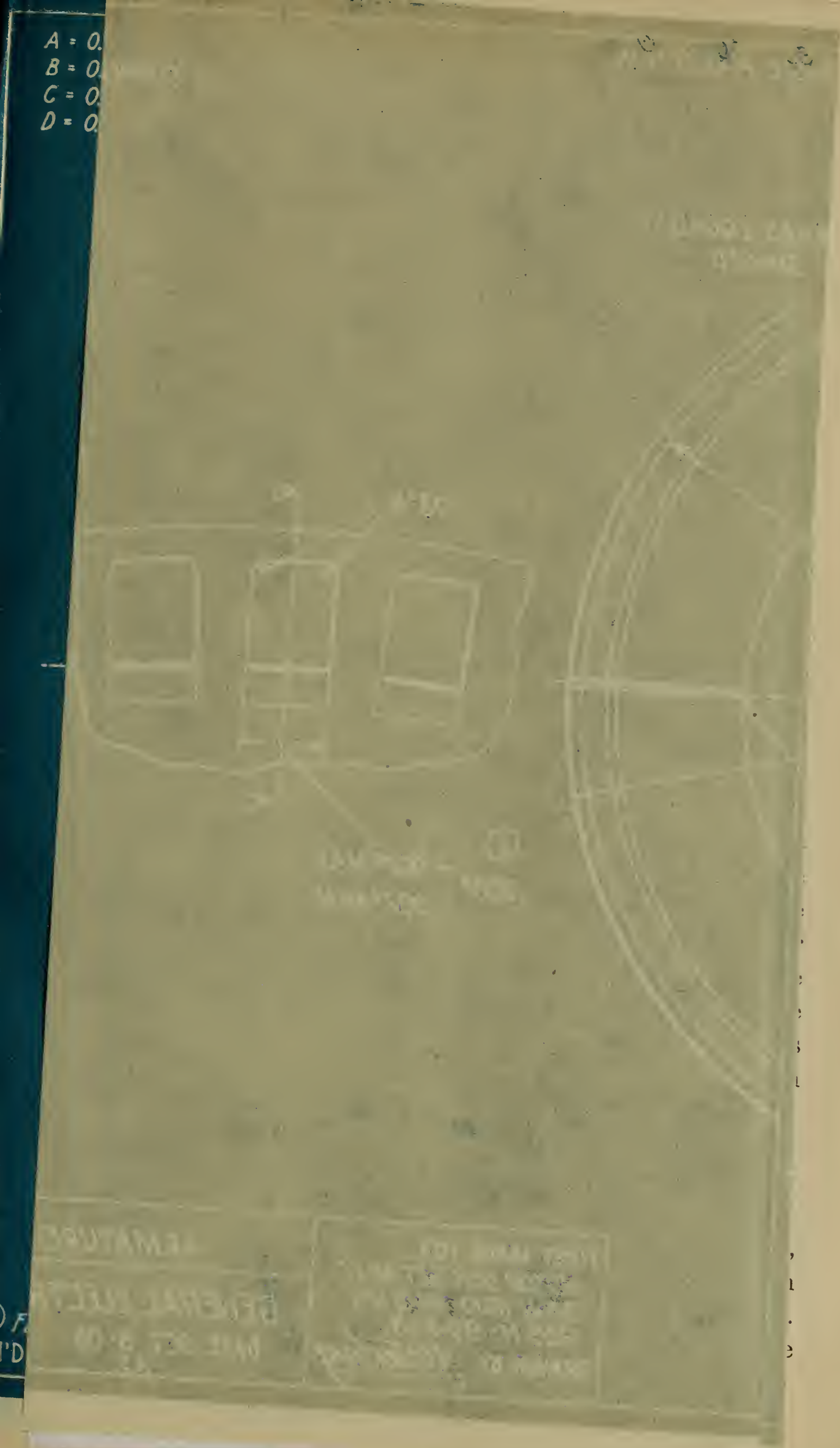

A = 0.
B = 0.
C = 0.
D = 0.

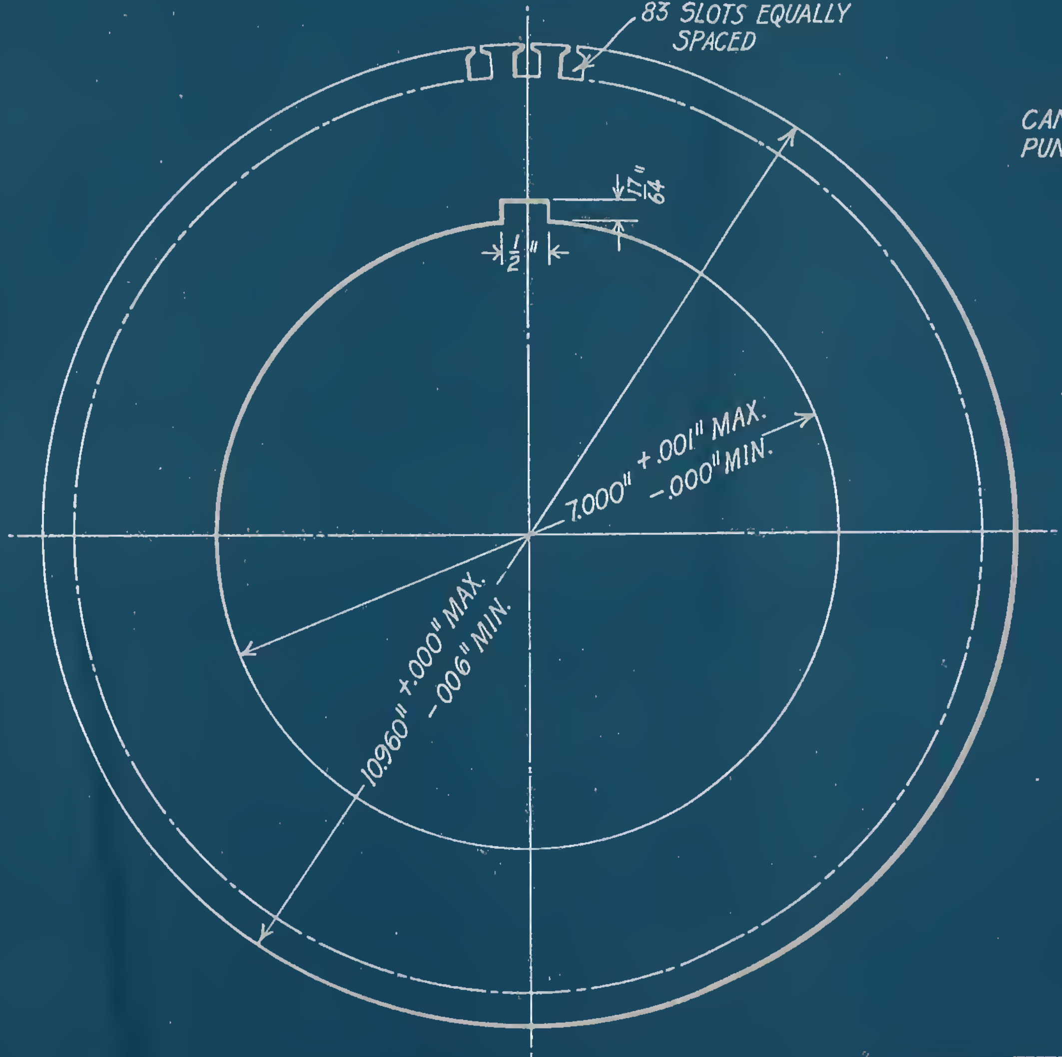
A = 0.0005"
B = 0.001"
C = 0.002"
D = 0.005"

THIRD ANGLE PROJECTION

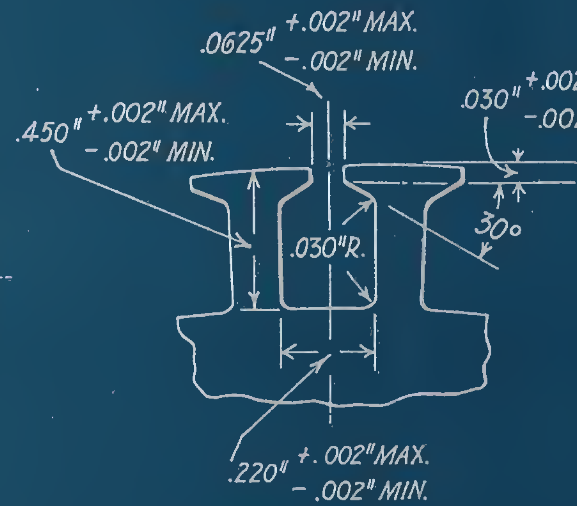
PUNCHED PART

STEEL SH. SOFT MATERIAL
STANDARD QUALITY
.014" THICK

PRINTS TO-
9
34
49[2]
0P
73
72[3]
38
38A



CAN BE MADE FROM INSIDE
PUNCHING OF FIELD PUNCHING 334361



(2)

FIRST MADE FOR MOTOR GEN. SET M.I.C. 3-12-KW 1800-440/125V. REG. N- 99438	ARMATURE PUNCHING
DRAWN BY J. Osterberg	GENERAL ELECTRIC CO., LYNN, MASS. DATE OCT. 8-08 A.S. 343065

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C = 0.002"
D = 0.005"

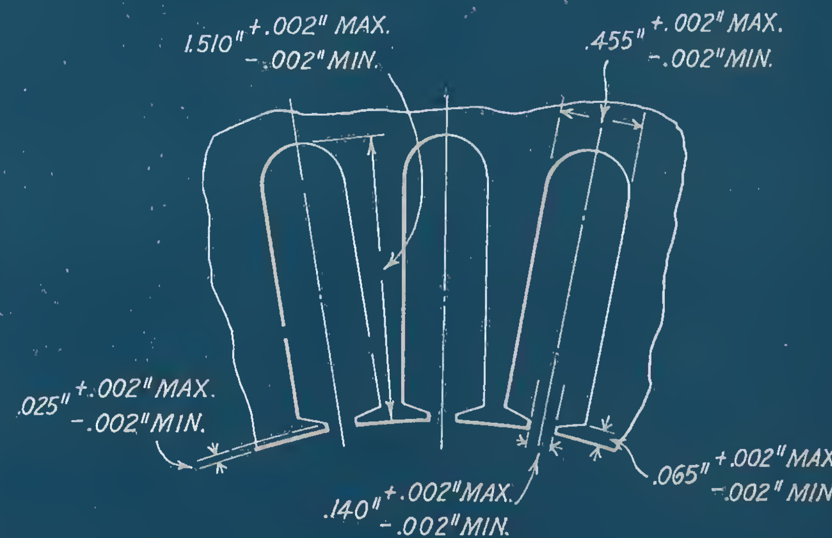
THIRD ANGLE PROJECTION

PUNCHED PART

STEEL SHEET SOFT STANDARD QUALITY .014" THICK MATERIAL

SIMILAR TO PUNCH 10154

PRINTS TO-
49
9
34
72³
OP
38²
38A
21
6
142



36 SLOTS

①

② APR. 29 1911
① JUNE 23-'10
CH'D DATE

XXIV - 1

FIRST MADE FOR MOTOR IND. KI FRAME #140 A-C 24 REG. 1372615 2/3	FIELD PUNCHING
DRAWN BY Purinton	GENERAL ELECTRIC CO., LYNN, MASS.
	DATE OCT. 26 '08 343089

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A small detail section *A–A* placed just over the center of the side view shows the form of the slot on the section line *A–A* drawn across the upper edge of the side view. These slots, twelve in number, are shown by dotted working lines in the side view and are spaced evenly completely around the armature head at its extreme left end as the piece is shown in the front view.

Careful study of the views shows that the armature head casting is a circular cup having three narrow shallow ribs cast onto the inner side of its rim. It is into the outer ends of these ribs that the cold rolled steel studs are screwed, as shown. At the opposite, or base, end of the casting is located the outer flange for the slots shown in the detail section *A–A*. Extension lines drawn from the working lines of the flange carry a dimension line and arrow points which show that the flange diameter is $4\frac{3}{4}$ inches. The body rim of the casting is to be finished to an outside diameter of $4\frac{1}{8}$ inches. The hole through the hub of the casting, it should be noted, is finished to a diameter of 1.375 inches, with a tolerance of but one-half of one-thousandth inch above size and no tolerance below the figured diameter. The keyway is figured in the side view as being $\frac{1}{4}$ inch wide and $\frac{9}{64}$ inch deep. It must be noted that the keyway is located in the hub hole on the center line of a rib and not in the thinner part of the hub. The reader should observe that the radius of the rim side of the $4\frac{3}{4}$-inch flange is curved to a $\frac{5}{8}$-inch radius as shown at the upper left of the front view and that a corresponding radius of $\frac{1}{2}$ inch for the flange slots is shown at the lower left of the front view. The centers for these radius lines are shown as 2 inches from the center line of the piece and $\frac{1}{4}$ inch from the edge of the piece. A lettered note placed just below the side view gives the tapped stud holes as 14-24 tap–3 holes. The hole in the outer end of the stud is given as 10-32 tap–$\frac{5}{8}$ inch deep.

PLATE XXIII, Nos. 1 and 2

DETAILS OF TYPICAL ARMATURE PUNCHINGS

General Data. Plate XXIII is made up of two **D**-size prints, each giving the details of a separate piece. For convenience in referring to them they have been given the numbers 1 and 2. Two other illustrations of a like construction are shown in Plate

XXIV. The pieces represented are punchings from sheet steel or sheet copper. The reader will note that a single complete view of each piece is shown supplemented by section details. The complete views, with the exception of blueprint No. 2 on Plate XXIV, are drawn to one-half scale in the original blueprint and the detail section views, in the original, are made to an enlarged scale about double size. These enlarged details show the form, size, and kind of holes to be made near the outer edge of the punching, as shown at the right of the complete views. A lettered note resting on an arrow states that there are to be eighty-three holes equally spaced around the punching.

Armature End Ring. The title plate gives blueprint No. 1 as an armature end ring punched from hard sheet copper 0.125 inch thick. The holes and the entire punching are made by using what is known as a perforating and shearing punch and die. The metal punched out of the hole, in this case, is turned, or bent, inward as shown in the enlarged details. A note with two arrow pointers tells us that this punching has two $\frac{1}{16}$-inch saw cuts.

Armature Punching. Blueprint No. 2 is an armature punching punched from standard quality soft sheet steel 0.014 inch thick. A single view shows the complete punching. It has a 7-inch hole of a maximum tolerance of 0.001 inch above size and the outside diameter is 10.960 inches with a minimum tolerance of 0.006 inch. The punching is provided with a keyway $\frac{1}{2}$ inch wide and $\frac{17}{64}$ inch deep. The outer rim is provided with eighty-three slotted holes equally spaced around the circumference. An enlarged view of these slots is placed just to the right of the complete view. Lettered notes with arrowhead pointers give all the slot dimensions.

PLATE XXIV, Nos. 1 and 2

DETAILS OF TYPICAL FIELD PUNCHINGS

Field Punching. In Plate XXIV are shown two blueprints of which No. 1 is a field punching punched from soft sheet steel, standard quality, 0.014 inch thick. One complete view only is given but, as in the blueprints shown in Plate XXIII, there is an enlarged view of the slots. This enlarged view gives complete details of the slots and the exact dimensions with all limiting tolerances. A note placed below the complete view tells us that the

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D = 0.005"

THIRD ANGLE PROJECTION

PUNCHED PART

STEEL SHEET SOFT STANDARD QUALITY .014" THICK MATERIAL

SIMILAR TO PUNCH 10154

PRINTS TO-
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38[2]
38A
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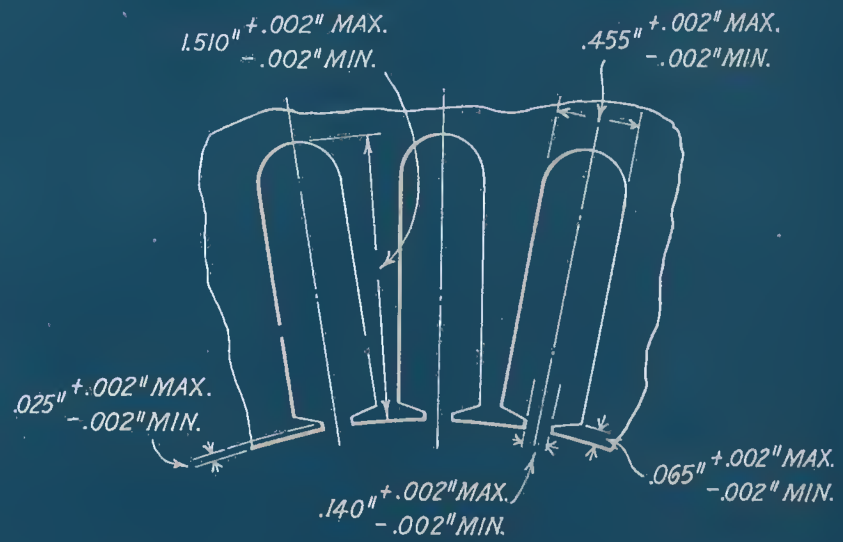

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36 SLOTS

M (2) APR. 29 1911
(1) JUNE 23 '10
CH'D DATE

XXIV - 1

FIRST MADE FOR MOTOR IND. KI FRAME # 140 A-C 24 REG. 1372615 2/3	FIELD PUNCHING
DRAWN BY Purinton ##	GENERAL ELECTRIC CO., LYNN, MASS. DATE OCT. 26 '08 343089

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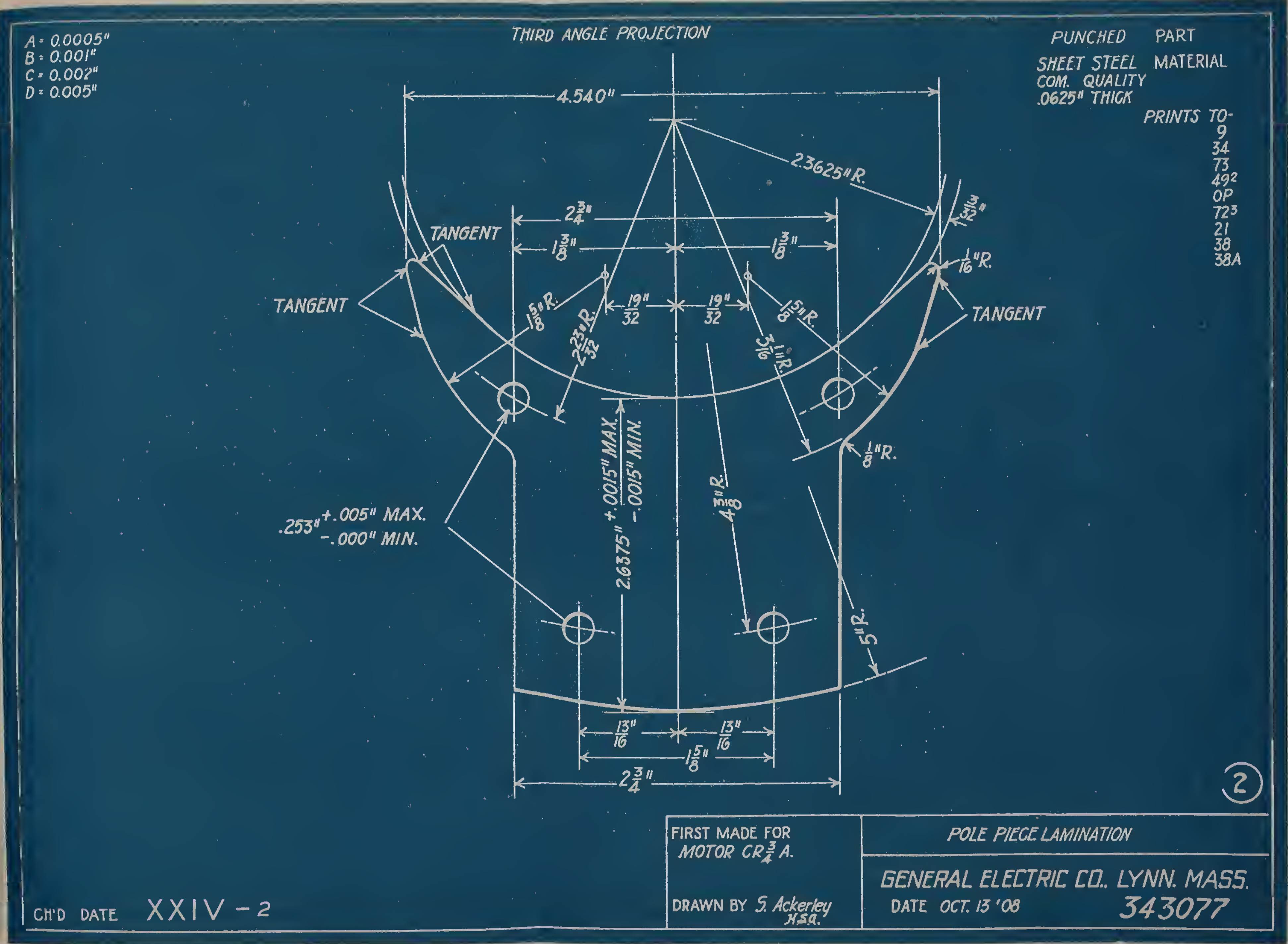
A = 0.0005"
B = 0.001"
C = 0.002"
D = 0.005"
THIRD ANGLE PROJECTION
PUNCHED PART
SHEET STEEL COM. QUALITY .0625" THICK MATERIAL
PRINTS TO- 9 34 73 49² OP 72³ 21 38 38A
4.540"
2.3625" R.
2 3/4"
1 3/8"
1 3/8"
3/32"
1/16" R.
TANGENT
TANGENT
TANGENT
1 5/8" R.
2 23/32" R.
19/32"
19/32"
1 5/8" R.
3 1/16" R.
1/8" R.
.253" +.005" MAX. -.000" MIN.
2.6375" +.0015" MAX. -.0015" MIN.
4 3/8" R.
5" R.
13/16"
13/16"
1 5/8"
2 3/4"
2
FIRST MADE FOR MOTOR CR 3/4 A.
DRAWN BY S. Ackerley H.S.A.
POLE PIECE LAMINATION
GENERAL ELECTRIC CO., LYNN. MASS.
DATE OCT. 13 '08
343077
CH'D DATE
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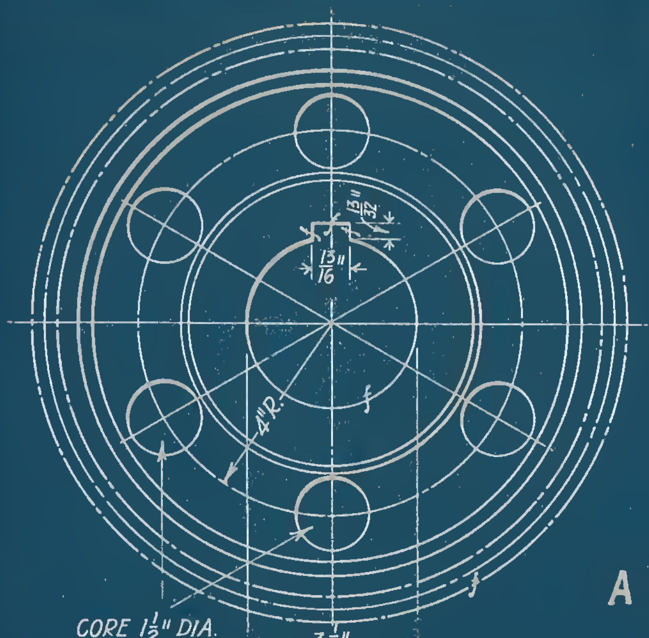

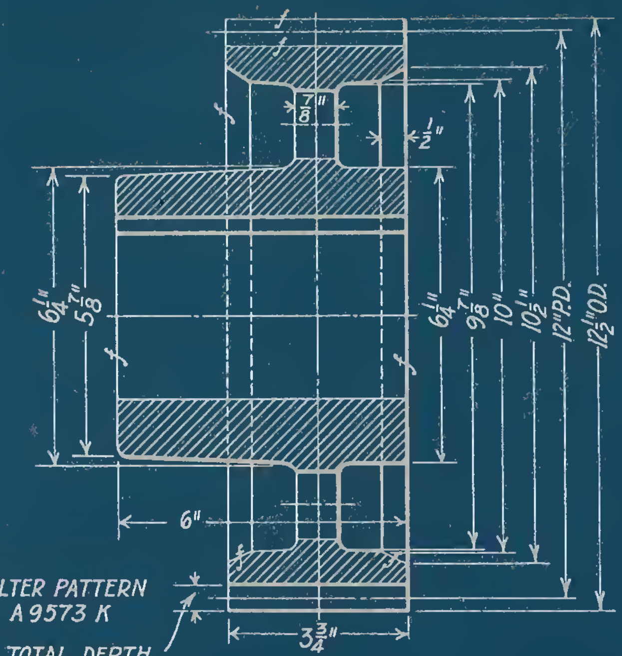

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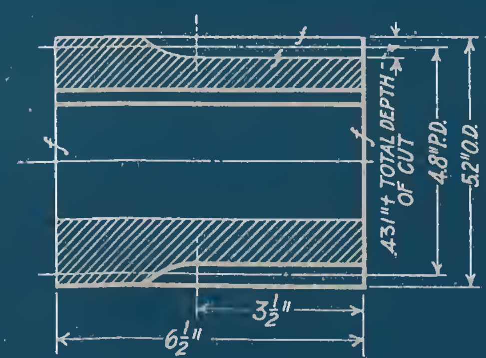
TOTAL DEPTH
OF CUT .539"+

48-TEETH- HOBBED $14\frac{1}{2}$° INV.
4 DIA. PITCH
12" PITCH DIA.

B



24-TEETH- HOBBED $14\frac{1}{2}$° INV.
5 DIA. PITCH
4.8" PITCH DIA.

BILL OF MATERIAL

MARK	NO. REQ'D	STOCK	DESCRIPTION
A	1	STEEL CAST .50-.60% CARBON .60-.80% MANG. TO BE THOR'LY ANNEALED	GEAR
B	1	C.H. STEEL FORGED .50-.60% C.	PINION

12" MERCHANT MILL
CONNECTING TABLE BETWEEN 2ND & 3RD PAIRS GEARS

SCALE 6 IN. = 1 FT.
CONTRACT BETH. ST. CO.
DATE 3-7-17
DR. G.P.M. CH. G.P.M.
TR. W.F.J. APP. E.J.Q.

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MORGAN CONSTRUCTION CO.
WORCESTER, MASS.

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slots are thirty-six in number. The punching has four lugs on its rim placed 90 degrees apart. The outer contour of each lug, the careful reader will observe, is made up of arcs of circles connected by short straight lines drawn tangent to the arcs. This gives an irregular outline to the lugs. The die maker will, of course, note that many of the dimensions for this punching are exact to quite small limiting tolerances.

Pole Piece Lamination. Blueprint No. 2 is a pole piece lamination, and the upper note informs us that it is punched from sheet steel, common quality, 0.0625 inch thick. When the reader considers the thickness dimensions of the punchings shown in Plates XXIII and XXIV, he will readily see why an edge view is not given except at an enlarged scale, as in the several detail views. Plate XXIV, No. 2, is drawn full scale in the original blueprint. Only two dimensions show limiting tolerances. Most of the radius lines are from a common center placed somewhat above the view and on its center line. Centers for the other radius lines are clearly defined by small circles inclosing the center points. Radius lines are clearly drawn and dimensioned with the arrow points touching the working lines of the view. The die maker should carefully locate that part of the working line to which each radius line refers.

PLATE XXV

GEARS USED ON 12-INCH MERCHANT MILL

The title plate tells us that Plate XXV shows gears used on a 12-inch merchant mill. The bill of material states that one of these is made from steel casting thoroughly annealed and the other from an open-hearth steel forging. In the original blueprint the views are drawn to a scale of 6 inches to 1 foot. Where two gears are shown and one is larger than the other, the smaller of the two is the pinion and the larger is the gear, and in reading this blueprint they will be referred to in this way.

The pinion is shown in two views, with the front view in section as if sliced through the center of its length. The end view at the left of the front view clearly shows the hole and its keyway through the pinion; other than this, it consists of three concentric circles representing the outside diameter, the pitch diameter, and

the root diameter of the pinion teeth. A lettered note placed just beneath the views tells the machinist that the pinion is to be hobbed and has twenty-four teeth of the regular 14½-degree involute form, five diameter pitch. The term diameter pitch refers the pitch of the teeth to the pitch diameter of the gear. Finish *f* marks show that the pinion is to be finished all over.

The views of the gear are arranged similarly to those of the pinion. Finish *f* marks show that the ends of the hub, the sides of the rim, the outer diameter of the rim, and the hole through the center are to be machined and that the inside of the gear rim on both its ends is chamfered as shown. The machinist should carefully note that the hole through the hub is bored 3½ inches in diameter and that the gear is to be forced onto its shaft with a pressure of 18 tons. The machinist should also observe that there are forty-eight 14½-degree involute teeth in the gear and that they are to be cut on a gear-hobbing machine. The pattern maker should especially note that there are six holes cored through the web of the gear. All dimensions and extension lines are clearly and plainly defined and so placed as to be easily read.

PLATE XXVI

BEVEL GEARS FOR ROLLS ON SHEET BAR AND SLAB-MILL STEAM FLYING SHEAR TABLE

The title plate of Plate XXVI informs us that the views shown represent a pair of bevel gears used on a 21-inch sheet bar and slab mill steam flying shear table. The bill of material shows them to be open-hearth steel castings thoroughly annealed. The front view of the gears is sectioned by a plane along their axes and shows the gear and the pinion with their teeth engaging, or in *mesh* as it is called. A pair of bevel gears are usually shown thus, and the reader should make himself familiar with this fact and should study every detail. The end view of the pinion and the end view of the gear are just sufficiently complete to show the hubs and the holes and keyways through the hubs.

A lettered note *A* states the number of teeth in the pinion, the form of the teeth, the pitch of the teeth, and how they are to be machined. A lettered note *B* gives like information for the gear. When reading these lettered notes, the machinist should

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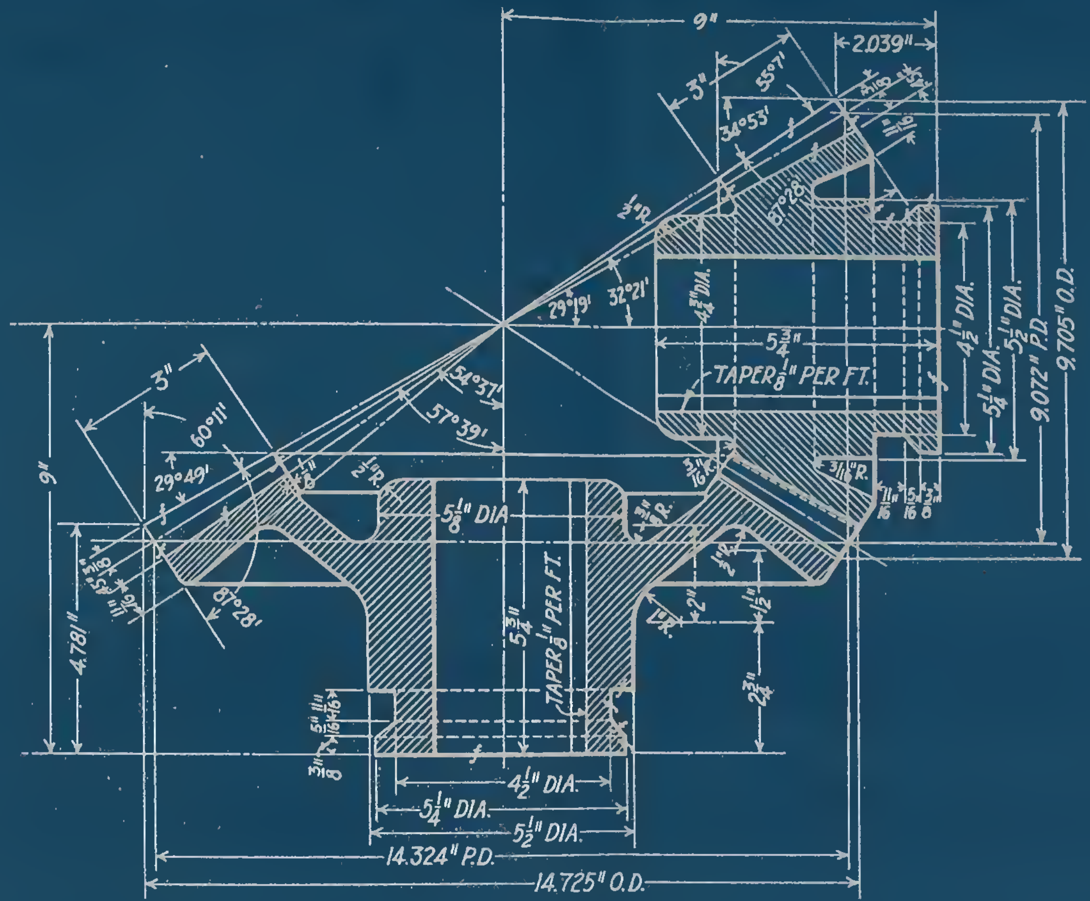

A 19 FINISHED TEETH
PLANED TO 20° INVOLUTE
1½" CIR. PITCH
9.072" PITCH DIA.
9.705" OUT. DIA.

·BILL OF MATERIAL·			
MARK	NO. REQ'D	STOCK	DESCRIPTION
A	1	O.H.STEEL	GEAR
B	1	SMOOTH	GEAR
		CASTING	
		.50-60% C. .60-	
		.80% MANG. TH-	
		OROUGHLY ANNEALED	

B 30 FINISHED TEETH
PLANED TO 20° INVOLUTE
1½" CIR. PITCH
14.324" PITCH DIA.
14.725" OUT. DIA.

21" SHEET BAR & SLAB MILL· STEAM FLYING SHEAR TABLE· BEVEL GEARS FOR ROLLS

SCALE 6 IN = 1 FT
CONTRACT SHARON S.H.CO.
DATE 3-12-18
DR. W.B.S. CH. BHS
TR. L.B.D. APP. RVE

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FROM
MORGAN CONSTRUCTION CO.
WORCESTER, MASS.

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not fail to observe that the gear teeth are 20 degrees involute instead of the ordinary $14\frac{1}{2}$ degrees, also that the pitch of the teeth is given as circular pitch instead of the more common diameter pitch. Circular pitch is the distance from the center line of a tooth to the center line of the next tooth and is measured along the pitch circle. In bevel gearing, it is measured at the largest pitch diameter.

The machinist, after carefully reading the lettered notes, is next concerned with the holes through the hubs of the gear and of the pinion. He will note that the gear is to be forced onto its shaft with a pressure of 15 tons and that in the pinion the hole should be a tight fit on the shaft. He will also observe that each keyway is to taper at the rate of $\frac{1}{8}$ inch per foot. The machinist's next concern is the outside diameters of the gear and of the pinion. By following the extension lines to their dimension lines he learns that the gear is 14.725 inches and the pinion 9.705 inches outside diameter. He then locates the angles which give him the cone form of the pinion and the gear blank and notes that they are given in degrees and minutes. By using a bevel protractor in his measurements he can readily machine the cone sides and edges to the required angles as given on the blueprint. Making the length of the tooth an even 3 inches as given completes the pinion and the gear blanks (so far as the tooth rims are concerned) ready for cutting the teeth. The back end of each hub is faced up and its end circumference is machined into a circular groove of definite dimensions which are easily found and noted.

Previous to planing the teeth, the machinist should locate the angle marking the bottom of the tooth space. This angle is known as the *cutting angle,* and in this blueprint the reader will find it for both gear and pinion near where the center lines of the gear and the pinion cross each other. For the gear, the cutting angle is 54 degrees 37 minutes and for the pinion it is 29 degrees 19 minutes. The total depth measured at the outer end of the teeth should be noted. This is given as $\frac{3}{8}$ inch$+$0.45 inch. As such gears as these are usually planed on a special gear-tooth planer, no further directions need to be given. The pattern maker will find in this blueprint all the necessary dimension lines, radius lines, and figured angles for a complete pattern for each gear.

PLATE XXVII

MOTOR COUPLING FOR ROD MILL DRIVE

Plate XXVII shows the parts of a motor coupling for a rod mill drive. The bill of material notes six parts *A–B–C–D–E–F* and gives the material from which each part is made and the number of each required. In the original blueprint all the views are one-quarter size, 3 inches to 1 foot. Lettered note *1* gives special shipping directions, and a most important note placed in the center of the end view gives explicit directions regarding the size of the hole and states that it is to be shrunk on the motor shaft. The front view of the coupling body *A* is sectioned through the center of its length. For the pattern maker, this is a simple job and he can make no mistakes in finding his dimension lines and figures.

The machinist who carefully reads the views will note that many of his dimensions are given to a special fixed gage. The note on the end view states that the hole is to be bored 0.007 inch small to allow a shrink fit. The keyway in the side of the hole is to be tapered $\frac{1}{8}$ inch per foot. A note at the hub end of the front view shows that this end of the hole is to be chamfered.

There are two hole keyways $\frac{15}{32}$ inch deep at the deeper end and a broad shallow keyway across the face of the flange part of the coupling, $1\frac{1}{8}$ inches deep and $3\frac{1}{2}$ inches wide to gage. Finish *f* marks on the working lines of both views indicate that the piece is machined all over. The smaller details of the coupling *B–C–F* are given near the right end of the blueprint. *F* shows two views of the key which fits the broad keyway machined across the face of the coupling flange; one end of the key is curved, as shown, to a radius of $10\frac{7}{8}$ inches. A $1\frac{9}{16}$-inch hole is shown drilled near the curved end and this helps us to understand that a flange bolt *B* passes through this end of the key when it is fitted in place in the face of the flange. The width dimension shows that it is to gage. The flange coupling bolts *B* with their nuts *C* are shown by a front and an end view. The front view shows the nut *C* in place, which is a common way of showing bolts and nuts. A hole is shown drilled through the body of the bolt near its threaded point for a $\frac{5}{16}$-inch cotter pin. The end view gives the shape of the bolt head and nut and shows it is chamfered at its outer corners.

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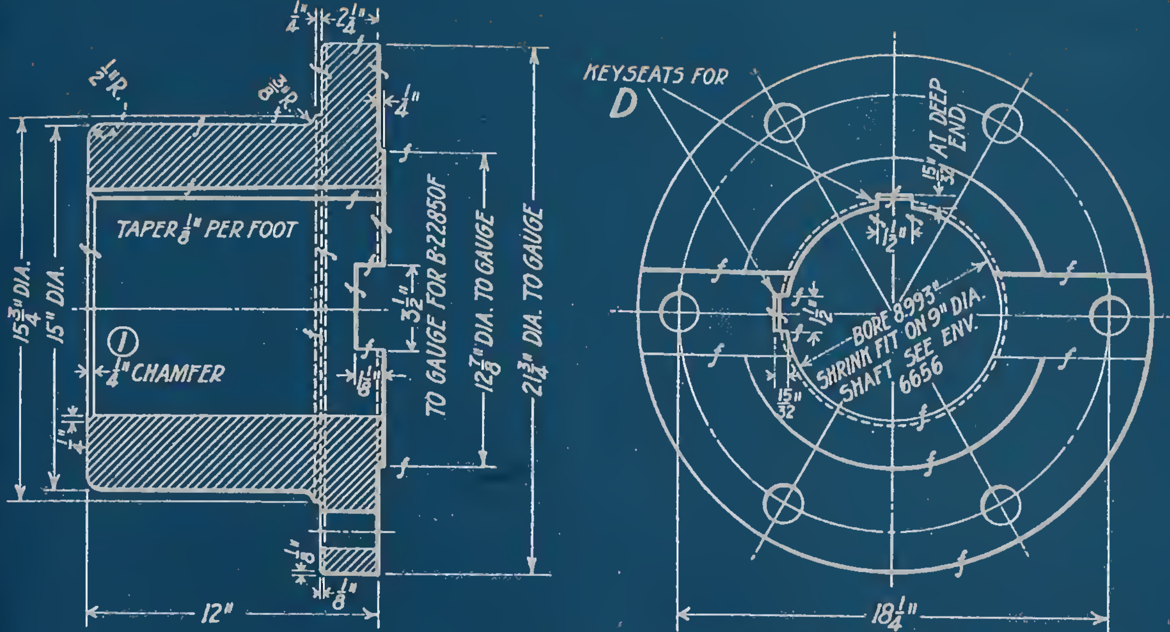
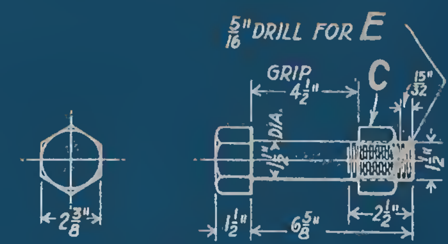
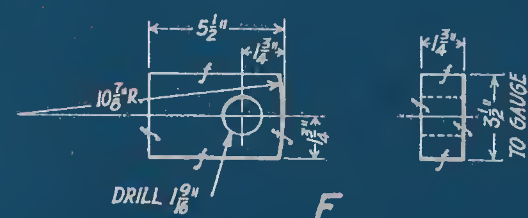


A

DIA. BOLT CIRCLE WITH 6 HOLES $1\frac{35}{64}$" DIA.
DRILLED TO JIG



B



F

·BILL OF MATERIAL·			
MARK	NO. REQ'D	STOCK	DESCRIPTION
A	1	O.H. STEEL CAST .20%-.30% C.	COUPLING
B	6	STEEL	$1\frac{1}{2}$" DIA. BOLT $6\frac{5}{8}$" LG.-HEX. HEAD
C	6	STEEL	$1\frac{1}{2}$" STD. HEX. NUT
D	2	KEY STEEL	$1\frac{1}{2}$" x $\frac{15}{16}$" KEY $11\frac{3}{4}$" LG. $\frac{1}{8}$" TAPER PER FT.
E	6	STEEL	$\frac{5}{16}$" DIA. COTTER 2" LONG
F	2	KEY STEEL	KEY $1\frac{3}{4}$" x $3\frac{1}{2}$" x $5\frac{1}{2}$"

① NOTE ÷ SEND AT ONCE TO ELECTRICAL DEPARTMENT OF ALLIS CHALMERS CO., MILWAUKEE, WIS. FOR THEIR ORDER 2-E-4136, A TEMPLATE FOR THE KEYWAYS AND A PIN GAUGE FOR THE BORE. LATER SEND COUPLING TO SAME ADDRESS TO BE SHRUNK ON MOTOR SHAFT.

ALTERATION OF ROD MILL DRIVE
DETAIL OF MOTOR COUPLING

SCALE 3 IN = 1 FT
CONTRACT INTER. I. & ST. CO.
DATE 1-12-18
DR. A.R.K. CH. A.R.K.
TR. H.F.K. APP.

REVISED			
1	3-4-18	6	
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FROM
MORGAN CONSTRUCTION CO.
WORCESTER, MASS.

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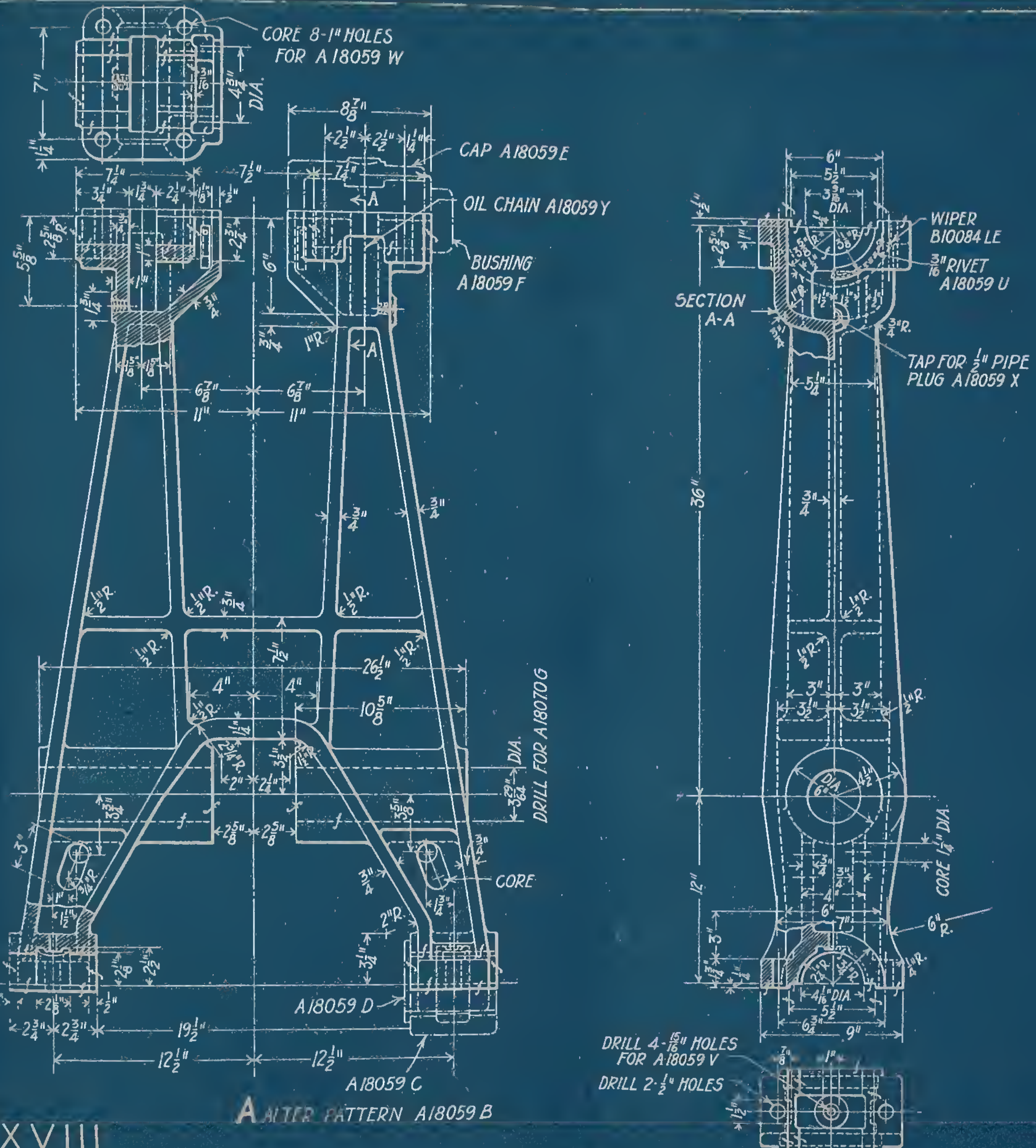

FOR ONE HOT BED

BILL OF MATERIAL			
MARK	NO. REQ.D	STOCK	DESCRIPTION
A	4	ST. CSTG.	BINDER ARM
A18059 A	4	C.I.	BASE
A18059 C	8	ST. CSTG.	CAP
A18059 D	8	LUMEN BRONZE	BUSHING
A18059 E	8	C.I.	CAP
A18059 F	8	LUMEN BRONZE	BUSHING
A18059 G	8	ST. CSTG.	SPRING SEAT
A18059 H	12	ST. CSTG.	SPRING SEAT
A18059 J	8	ST. CSTG.	SPRING SEAT
A18059 K	16	SPR. ST.	SPRING
A18059 L	4	SPR. ST.	SPRING
A18059 M	16	SPR. ST.	SPRING
A18059 N	4	C.R. ST.	PIN 3 7/16" DIA. X 30 3/4" LG.
A18059 U	8	STEEL	RIVET 3/16" X 3/4" LG.
A18059 V	16	BAR ST.	BOLT 7/8" x 4 1/2" & LOCK WASHERS
A18059 W	32	BAR ST.	BOLT 7/8" x 6 1/4" & LOCK WASHERS
A18059 X	8	C.I.	1/2" PIPE PLUG
A18059 Y	8	TINNED ST.	UNIVERSAL CHAIN 5/16" X 18 1/2"
A18059 Z	4	BAR ST.	SET SCREW 3/4" x 2 1/4"
B10084 GA	8	C.I.	OIL COVER
B10084 HA	8	SP. BRASS	SPRING
B10084 KA	8	STEEL	RIVET 1/2" X 1 3/4"
B10084 LE	8	SP. BRASS	WIPER
A18070 B	4	ST. CSTG.	SHEAVE
A18070 D	4	ST. 20% C	SHAFT
A18070 E	4	BAR ST.	SPRING ROD
A18070 F	4	BAR ST.	SPRING ROD
A18070 G	4	C.R. STEEL	PIN
A18070 H	4	C.R. STEEL	PIN
A18070 J	4	C.R. STEEL	PIN
A18070 M	4	STEEL	COTTER 5/8" X 5"
A18070 N	16	STEEL	COTTER 1/4" X 1 1/2"

21" SHEET BAR & SLAB MILL
COOLING BEDS
BINDER ARM FOR ROPE TAKE-UP

SCALE 3 IN = 1 FT
CONTRACT SHARON S.H. CO.
DATE 4-22-18
DR. J.M.M. CH. F.A.L.
TR. R.W. APP. E.J.Q.

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FROM
MORGAN CONSTRUCTION CO.
WORCESTER, MASS.

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PLATE XXVIII

BINDER ARM FOR ROPE TAKE-UP

The title plate shows that the views in Plate XXVIII are of a binder arm for rope take-up used on the cooling beds of a 21-inch sheet bar and slab mill. A long bill of materials is given. The title also tells us that in the original blueprint the views are drawn to a scale of 3 inches to 1 foot.

The views are complete and this is a very interesting blueprint for either a pattern maker or a machinist. For example, the reader will note that at the right-hand upper part of the front view the bearing cap is shown in place on its bearing by a series of dash and dot lines known as *broken lines*. This gives a sort of *skeleton* view of the cap. At the same place is a skeleton view of a bushing marked *A18059F*. Looking this number up in the bill of materials, the reader finds that the bushing is made of lumen bronze and that eight are required for four binder arms. Directly below this part of the view and at its extreme lower edge, similar skeleton views are shown of a cap *A18059C* and a bushing *A18059D*. In looking for these numbers in the bill of materials, the reader finds the names of the parts, the material used, and the number required for four binder arms. When the reader has carefully located each part in the bill of materials, he should consider its name, the number required, and the material used. The bill of materials shows that the binder arm is marked *A*, that it is made from a steel casting, and that four are required.

Another interesting matter relating to this blueprint is the method used in sectioning various parts of the views to open up the bearings clearly to the reader. A bottom view of the lower bearing is shown placed just below the side view and a similar top view of the upper bearing is placed just above the left side of the front view. The machinist must finish the four bearings to fit the caps and the lumen bronze bushings and drill a pin hole $3\frac{29}{64}$ inches in diameter for *A18070G* through the length of two circular hubs plainly showing in the lower half of the front and the side views. In addition, he must drill a $\frac{1}{2}$-inch oil hole in the upper part of the lower bearing and a hole just below each of the upper bearing and tap for a $\frac{1}{2}$-inch pipe plug. The machinist will also note that both ends of all four bearings and the inner ends of the pin

hubs are finished and that a spring brass wiper is riveted into each of the upper boxes near its inner end.

The pattern maker will note that the framework of the piece is a simple rib construction for supporting the several bearings and hubs and that the working lines are well dimensioned.

The upper bearings are complicated by having to be cored for an oil well, or chamber. The oil in this chamber is distributed to the shaft by means of a tinned steel universal chain *A18059Y* hung on the shaft into the enlarged part of the center of the oil chamber. The pattern maker should also note the special cored holes through the outer and the inner ribs showing just below the long pin hubs. Finish *f* marks placed across certain working lines of the view show the pattern maker for which surfaces he must allow an excess of metal for the machinist's needs. The bolt holes in the upper bearings for *A18059W* are cored, while those in the lower bearings for *A18059V* are drilled by the machinist.

PLATE XXIX

PARTS OF SHUTTLE MECHANISM FOR LOOM

Plates XXIX, XXX, and XXXI are each made up of four small blueprints originally $4\frac{1}{2}'' \times 5\frac{1}{2}''$ and show the practice of the Crompton-Knowles Loom Company. The small $4\frac{1}{2}'' \times 5\frac{1}{2}''$ blueprints are those used in their shops as working blueprints. Each small blueprint is from a *free-hand* sketch of some part of one of their machines and contains all that the workman needs to know when machining the piece. Blueprints made like those which we have been studying are used by the pattern maker.

A number placed in a circle has been added to each small blueprint to make it easy to refer to and each is provided with a title plate which contains certain information useful to the workman. For example, the title plate of the small blueprint No. 1 tells us that the piece is a rocker iron for a shuttle change motion on a medium duck loom and that the material is cast iron. Blueprint No. 2 shows the lower part of a shuttle carrier; No. 3, a stand for a lifter; and No. 4, the top part of a shuttle carrier. In many of these blueprints no over-all dimensions are given, and as they are not made to any particular scale of sizes, in such cases the sketch artist places the over-all length of the piece in the upper

NO. 10

21"

TITLE
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1

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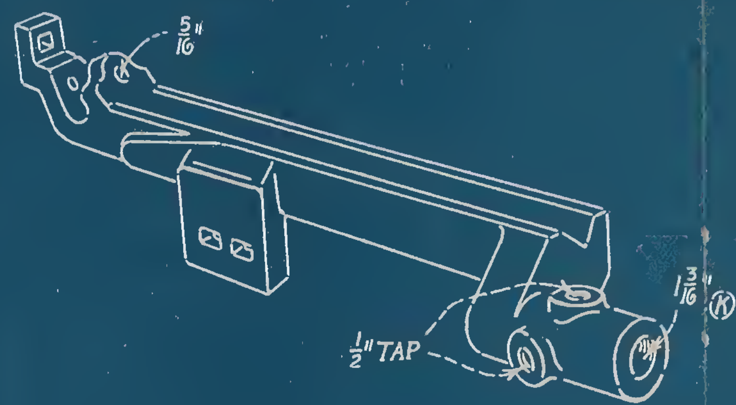


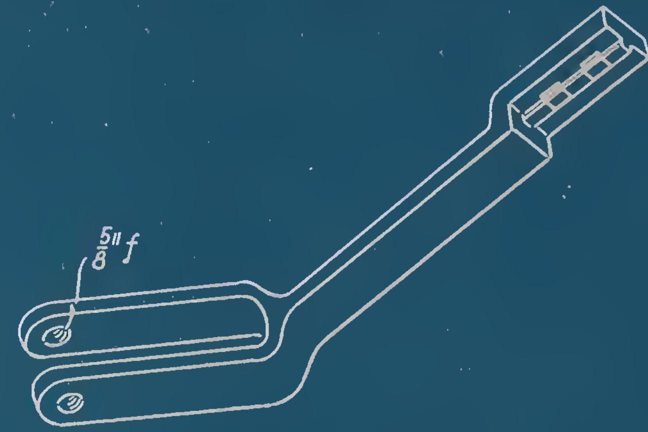
TITLE ROCKER IRON
MOTION SHUTTLE CHANGE (LAY)
FOR DETAIL SEE

LOOM MED. DUCK
MATERIAL C.I.
DATE 4-10-18

NO. 108158-9

2

17



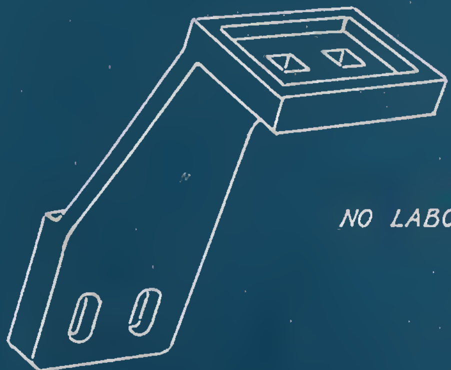
TITLE SHUTTLE CARRIER LOWER PART
MOTION SHUTTLE CHANGER
FOR DETAIL SEE

LOOM MED. DUCK
MATERIAL C.I.
DATE 4-12-18

NO. 108154-5

3

9"



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TITLE STAND FOR LIFTER ROD GUIDE
MOTION SHUTTLE CHANGE
FOR DETAIL SEE

XXIX

LOOM MED. DUCK
MATERIAL C.I.
DATE 4-10-18

NO. 108156-7

4

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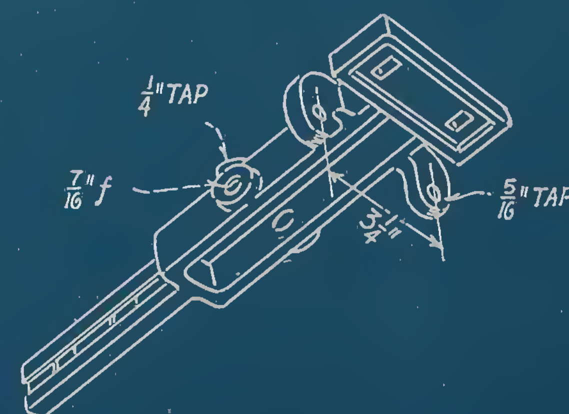
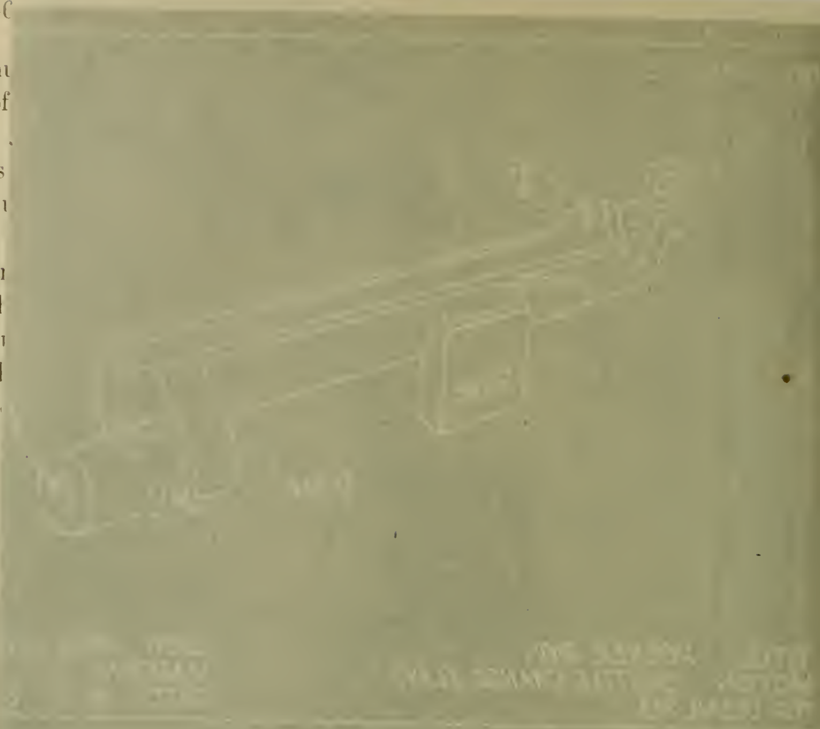


TITLE SHUTTLE CARRIER TOP PART
MOTION SHUTTLE CHANGER
FOR DETAIL SEE

LOOM. MED. DUCK
MATERIAL C.I.
DATE 4-12-18



NO. 108829

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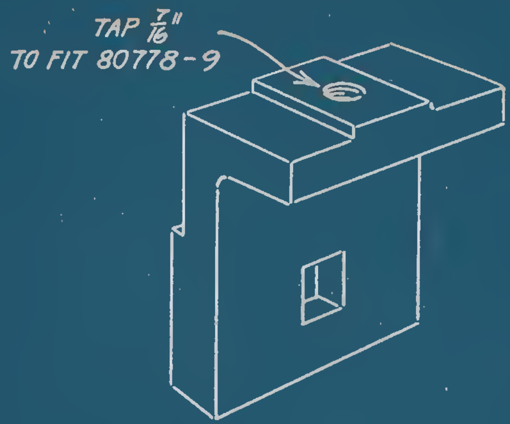


TITLE STAND FOR GEAR GUARD
MOTION CAM HAR MO.
FOR DETAIL SEE

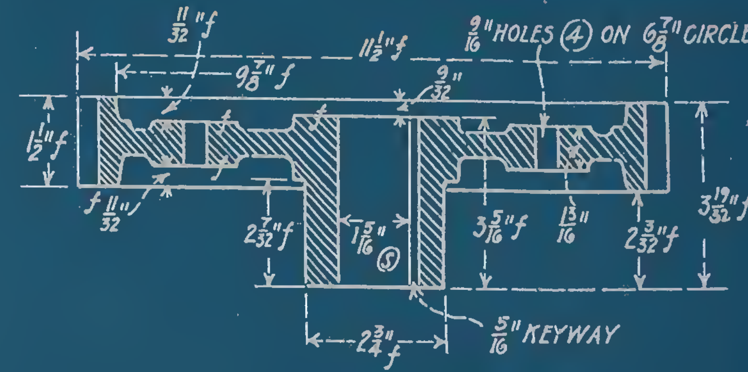
LOOM WEBBING
MATERIAL C.I.
DATE 6-15-18

NO. 108827

$11\frac{1}{2}''$

CUT TEETH $\frac{44\ T.}{4\ P.}$

2



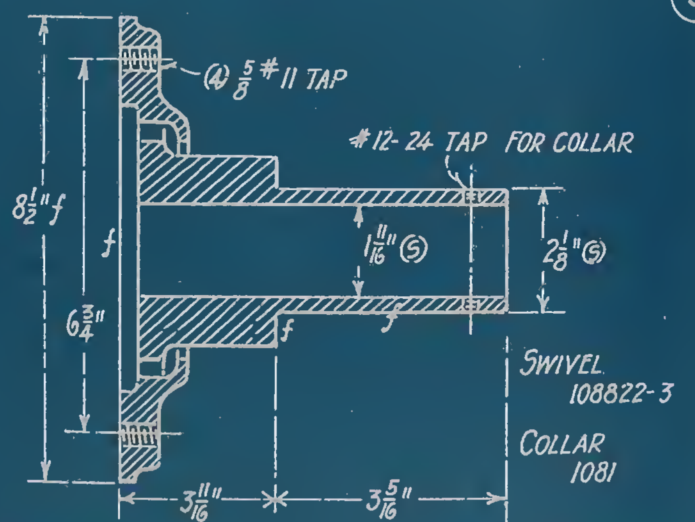
TITLE SPUR GEAR ON CRANK SHAFT
MOTION DRIVE
FOR DETAIL SEE

LOOM SILK
MATERIAL C.I.
DATE 6-18-18

NO. 108824

$8\frac{1}{2}''$

3



TITLE HUB FOR PULLEY
MOTION DRIVE
FOR DETAIL SEE

XXX

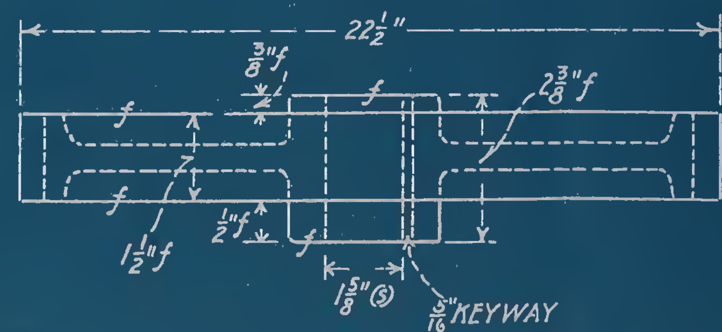
LOOM PRESS CLOTH
MATERIAL C.I.
DATE 6-25-18

NO. 108826

$22\frac{1}{2}''$

CUT TEETH $\frac{88\ T.}{4\ P.}$

4



TITLE SPUR GEAR ON BOTTOM SHAFT
MOTION DRIVE
FOR DETAIL SEE

LOOM SILK
MATERIAL C.I.
DATE 6-18-18

left-hand corner in small numerals over or on a short line; for example, the piece in blueprint No. 1 is 21 inches long. While this dimension is of no value to the machinist, it does aid the stores keeper in handling the castings, for, while each sketch is a picture of the piece in so far as its outlines are concerned, unless the small numerals are read, there is nothing in the view to indicate whether the piece is inches or feet in length. While such working blueprints are not commonly used, it is worth the reader's while to study them, as they show very clearly the use of free-hand sketches.

It must be borne in mind that in certain lines of machine building, while a given machine may consist of a great many parts, each part may be a very simple piece requiring but little or no machining; for example, blueprint No. 1 shows a piece of work that is to have four drilled holes, two of which are tapped; No. 2 shows a piece with one drilled hole; No. 3 is marked "no labor" and shows a piece of work in which the holes are made in the foundry by the use of properly shaped cores; and No. 4 is a little more complicated, having two $\frac{5}{16}$-inch tapped holes $3\frac{1}{4}$ inches apart and one $\frac{1}{4}$-inch tapped hole with the end of the hole boss, faced.

PLATE XXX

DETAILS OF GEARED MECHANISM USED ON CROMPTON-KNOWLES LOOM

In Plate XXX, blueprint No. 1, which represents a stand for a gear guard, is shown in the same manner as the blueprints in Plate XXIX. When pieces are sketched in this way, they are said to be shown in *perspective;* they are also termed picture sketches, as they are shown tipped and swung around from the regular squarely viewed position of the ordinary blueprint. Blueprints Nos. 2, 3, and 4, Plate XXX, representing a spur gear on the crankshaft, a hub for a pulley, and a spur gear on the bottom shaft, respectively, are shown viewed squarely from the front, and the real difference between them and most of the blueprints which we have studied lies in their being made by free-hand pen methods rather than by the use of drawing instruments. An end view of blueprint No. 2, 3, or 4 would show a series of concentric circles. Finish *f* marks indicate the working surfaces which are to be finished by some method of machining.

In Nos. 2 and 4 two dotted working lines and a lettered note tell us that a $\frac{5}{16}$-inch keyway is to be machined in the surface of the holes through the central hubs of these gears. In the case of No. 2, a lettered note states that four $\frac{9}{16}$-inch holes on a $6\frac{7}{8}$-inch circle are to be drilled through the web of the gear, and the sketch shows that these are placed in slightly raised hubs, or bosses. It will be noted by the careful reader that, while in most instances the finish *f* marks are placed in the usual manner on the working lines of the views, in some cases they are given with the dimension figures. As a case in point, take the diameter of the longer hub in No. 2. Here the finish *f* mark follows the dimension figures thus, $2\frac{3}{4}''$ *f*. Several similar cases will be noted in these sketches by the interested reader. While most machine gears have "cut" teeth, this is not universally so on certain lines of machinery and lettered notes at the top of No. 2 and No. 4 state that these gears have "cut" teeth.

PLATE XXXI

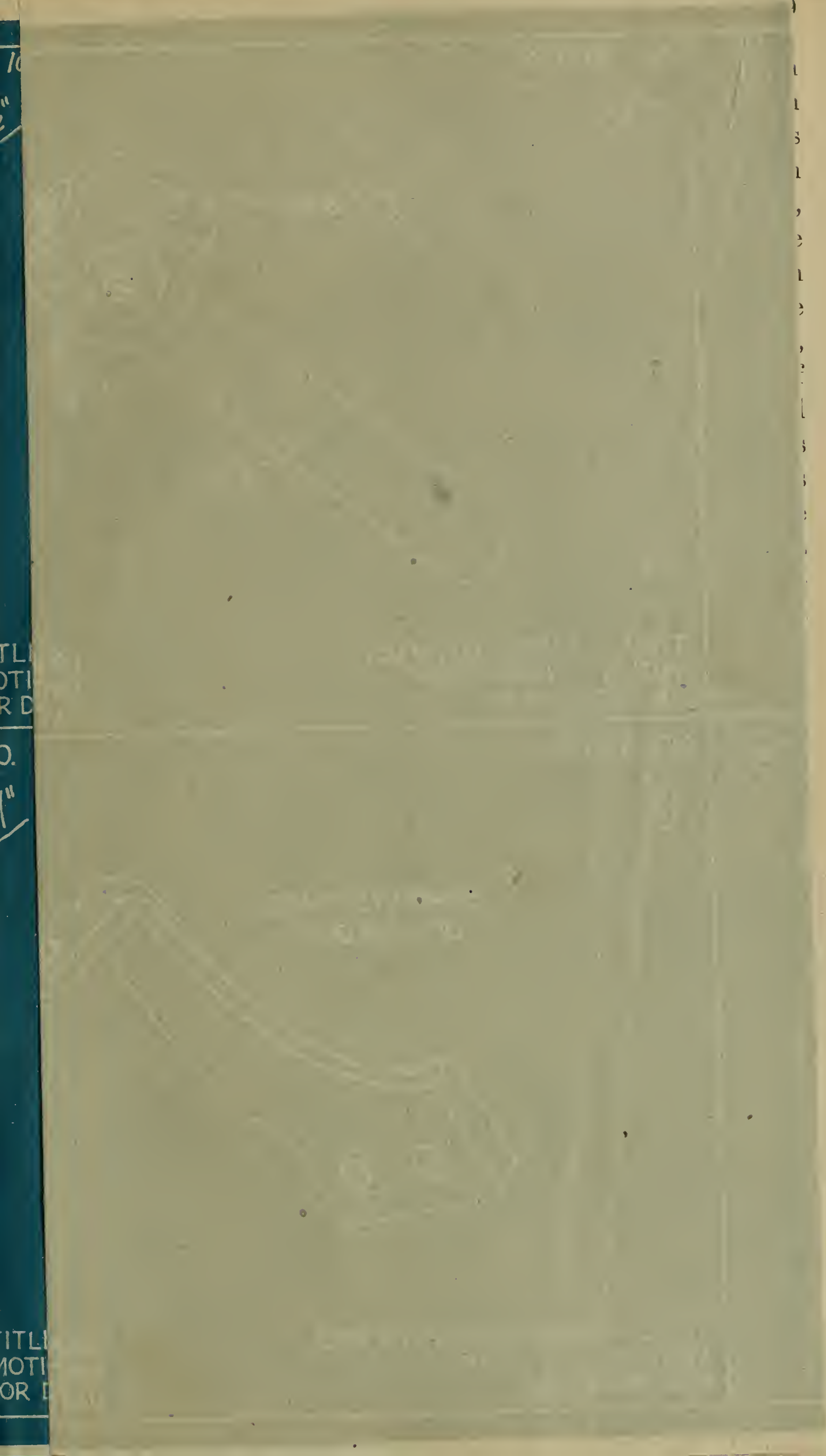
MISCELLANEOUS MECHANISMS USED ON CROMPTON-KNOWLES LOOMS

Plate XXXI, like the two preceding plates, is made up of four blueprints originally $4\frac{1}{2}''\times5\frac{1}{2}''$. Reading the title plate, we learn what each piece is and the material used. Blueprints Nos. 1, 2, and 4 show, respectively, a stand for a shipper and lock lever, an angle iron post, and a guide for a lifter rod, and they are picture, or perspective, views. No. 3 is the ordinary type of free-hand sketch and shows a front and an end view of a ratchet and pinion. While no special directions are needed in reading, attention is called in No. 1 to the $\frac{5}{8}$-inch hole near the lower part of the piece. While this shows the stud *#4757* in place, the stud is evidently a separate piece. In No. 2, the long shank has no finish *f* marks but is marked $\frac{3}{4}''$ *f*. In No. 3 two views are necessary to show that one set of teeth is on a slender hub.

PLATE XXXII

BRASS CHECK VALVE

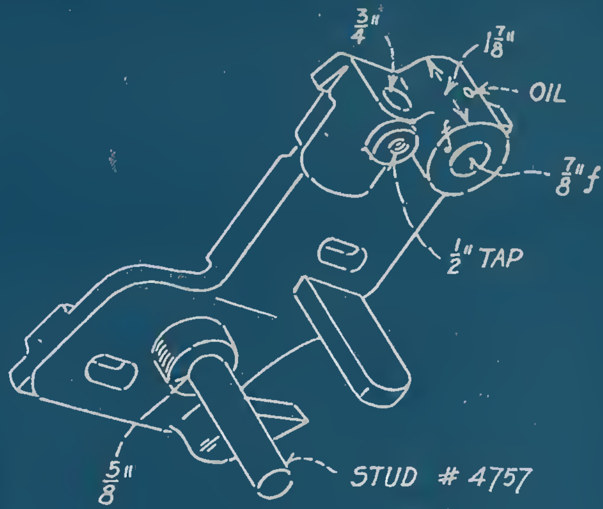
First-Angle Projection. While "Mechanical Drawing," Parts I, II, and III, does not analyze in detail the method of projection



NO. 108174-5

9½"

(1)



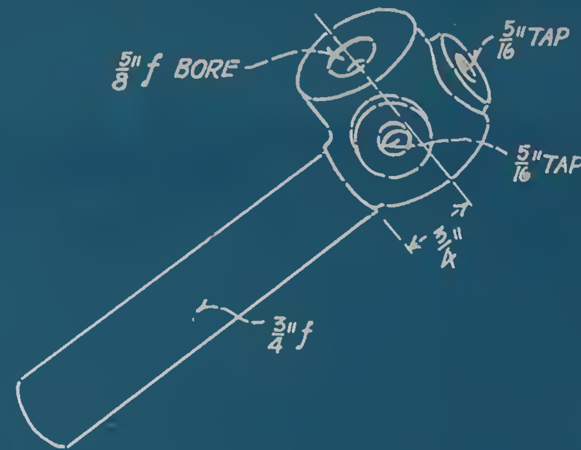
TITLE STAND FOR SHIPPER & LOCK LEVER
MOTION . DRIVE
FOR DETAIL SEE

LOOM TIRE FABRIC
MATERIAL C.I.
DATE 4-15-18

NO. 108178

5½"

(2)



TITLE ANGLE IRON POST
MOTION WARP STOP
FOR DETAIL SEE

LOOM PROV. COTTON
MATERIAL C.I.
DATE 4-15-18

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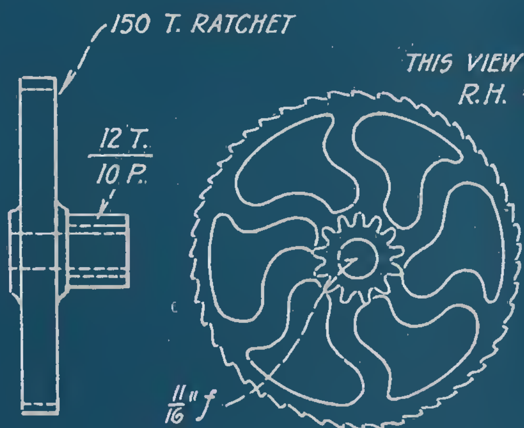
(3)

THIS VIEW SHOWS
R.H. #108176



TITLE RATCHET & PINION
MOTION TAKE UP
FOR DETAIL SEE

XXXI

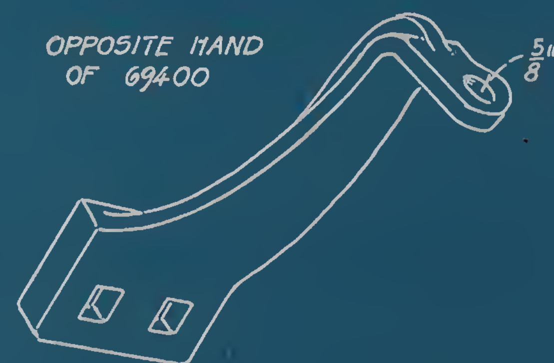
LOOM TAPE
MATERIAL C.I.
DATE 4-16-18

NO. 108179

7¾"

(4)

OPPOSITE HAND
OF 69400



TITLE GUIDE FOR LIFTER ROD
MOTION LAY
FOR DETAIL SEE

LOOM CROMPTON COT. BLANK.
MATERIAL C.I.
DATE 4-17-18

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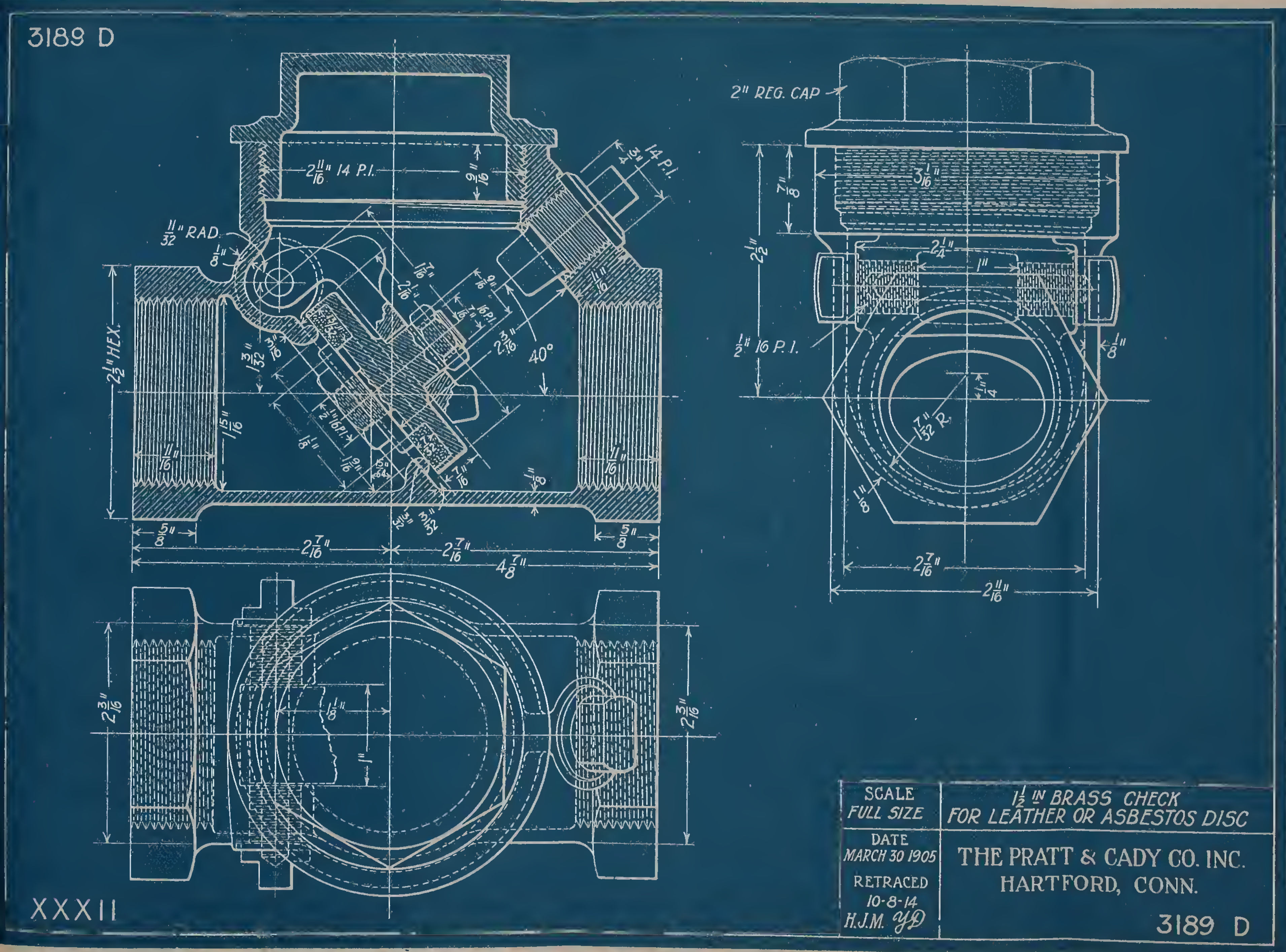
3189 D
2" REG. CAP
2 11/16" 14 P.I.
14 P.I.
11/32" RAD.
2½" HEX.
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40°
½" 16 P.I.
7/32 R.
4 7/8"
XXXII
SCALE
FULL SIZE
DATE
MARCH 30 1905
RETRACED
10-8-14
H.J.M.
1½ IN BRASS CHECK
FOR LEATHER OR ASBESTOS DISC
THE PRATT & CADY CO. INC.
HARTFORD, CONN.
3189 D

used in Plate XXXII, readers of blueprints often have such placed in their hands. The blueprints of machine parts shown in this text are, with this one exception, drawn in what is known as third-angle projection. In addition to what this book contains on views and their arrangement, "Mechanical Drawing," Part III, defines and illustrates first-angle and third-angle projection and the blueprint reader should study the opening pages of Part III. In Fig. 97, Part III, the reader will note that the lines of the piece viewed are sent forward on a plane surface. In other words, instead of placing the object we are viewing on the far side of some material like plain glass and viewing it through the glass and then making on the glass a sketch of what we see, the object is placed in front of the glass and we make the sketch on the glass as if we sighted along its edges and drew lines on the glass in line with the edges we were sighting. Looking at an object in this manner places the right end view in the blueprint at the left side of the front view instead of at the right side as in previous blueprints, and the surface lines seen in looking down on the top of the object are shown below the front view.

Placing of Views. If this method is clear in the reader's mind, let him return to Plate XXXII. He will observe that the front view of this 1½-inch brass check valve has been placed at the upper left-hand corner of the sheet. Just below the front view and centered with it is the view one would get of this valve if he were viewing it on its top side, or upper surface. By the regular third-angle system of placing views, the top view would be shown above the front view. The end view, as the careful reader will note, represents the view one would get if looking at the left end of the front view. While it is, then, a view of the left end of the valve and would, in ordinary view arrangement, be placed at the left of the front view, it is by the first-angle arrangement of views placed at the right of the front view. In tracing the location of a line from one view to another, the blueprint reader will need to use care if he is not accustomed to this method of showing views.

Details of Blueprint. Other than the arrangement of views, this blueprint is easily read, having, as it does, a hollow spherical body with hexagon ends and a circular hole in its upper side, a hexagon cap screwed into the top side hole, and an internal

swing hinged valve flapper. A tapped hole in the upper right corner of the body is made at an angle of 40 degrees with the axis of the valve body and into this is screwed a special plug as shown. The flapper is hinged on a small diameter spindle which is centered and held in place by two bearing plugs placed opposite each other in the body of the valve. The flapper consists of a hinged frame, a circular disc having a ring of leather or asbestos in its under side groove, a bolt, a nut, and a washer to hold the ring in the disc groove and the ring and disc onto the hinged frame.

PLATE XXXIII

SPINDLE

When interpreting Plate XXXIII, the reader will note from the title plate that the spindle is made from 15-point machine steel. Fifteen point when used in this manner means that the carbon content in the steel is fifteen-hundredths of one per cent. The shop man and the mill man shorten this by saying or writing it 15 point. A front view only is needed to show all the necessary outlines of the spindle and to give all the necessary dimensions for the workman as an end view would consist of a series of concentric circles except for the keys and their seatings.

Dotted lines centered with the center line of the work and drawn from end to end of the view show a hole through the length of the spindle. A lettered note tells us that in the right-hand, or nose, end of the spindle this hole is No. 12 taper to a plug depth of 6 inches. In producing the hole, the workman would first drill a hole $7\frac{5}{8}$ inches deep plus or minus $\frac{1}{8}$ inch, using a $1\frac{3}{16}$-inch drill, and then he would continue the hole completely through the length of the spindle, using a 1-inch drill. A lettered note with an indicating arrowhead informs us that the rear end of the hole is to be chamfered $\frac{1}{8}$ inch for center. Another lettered note states that the spindle bearings are to be pack hardened at least $\frac{1}{16}$ inch deep. A lettered note placed near the nose of the spindle tells us that the $3\frac{1}{4}$-inch and the $3\frac{1}{2}$-inch diameters are to be a forced fit in part #4470. Some makers of working blueprints use the term press fit instead of force fit. Either term would indicate that part #4470 is to be pressed onto the spindle at the places indicated by the arrow points. The lettered

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-25-15
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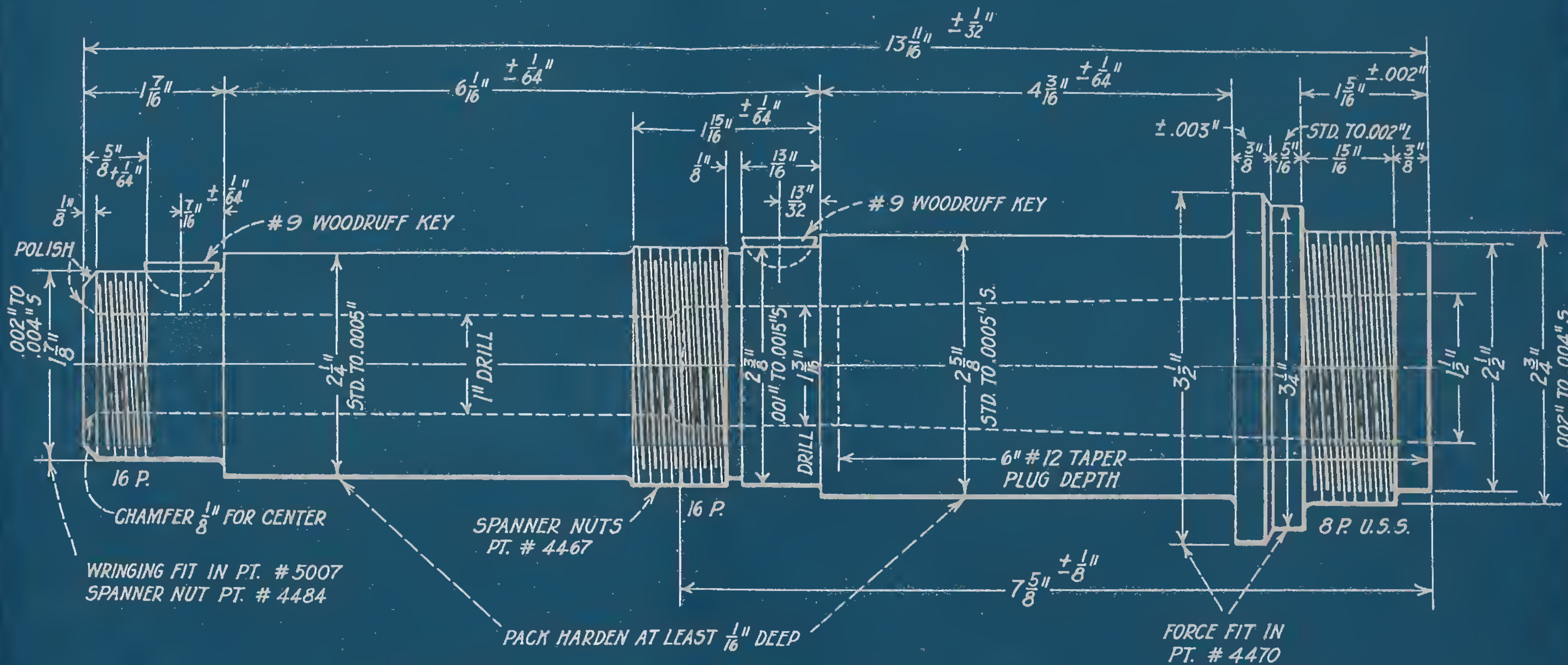

WHEN TURNING LEAVE NO FILLET UNLESS CALLED FOR.
WHEN GRINDING LEAVE FILLET MADE BY WHEEL NOT TO EXCEED 1/32" RADIUS UNLESS OTHERWISE CALLED FOR.

DO NOT THREAD UNTIL AFTER HARDENING & GRINDING ON DIAMETERS

4-9-18
8-25-15
DATE CHANGED

5018

15 PT. MACHINE STEEL

SCALE FULL SIZE

XXXIII

Unless Otherwise Specified, Limits On This Drawing Are ±.005"
Dimensions Of Angles ±1°. Reamed And Bored Holes St'd To .001" Small.

DRAWN BY G.M.D./J.
CHECKED BY A.G.B./B.
APPROVED BY H.W.B. A.T.
DATE 4-9-18

NAME SPINDLE
FOR JOB - 10" L.S.A.

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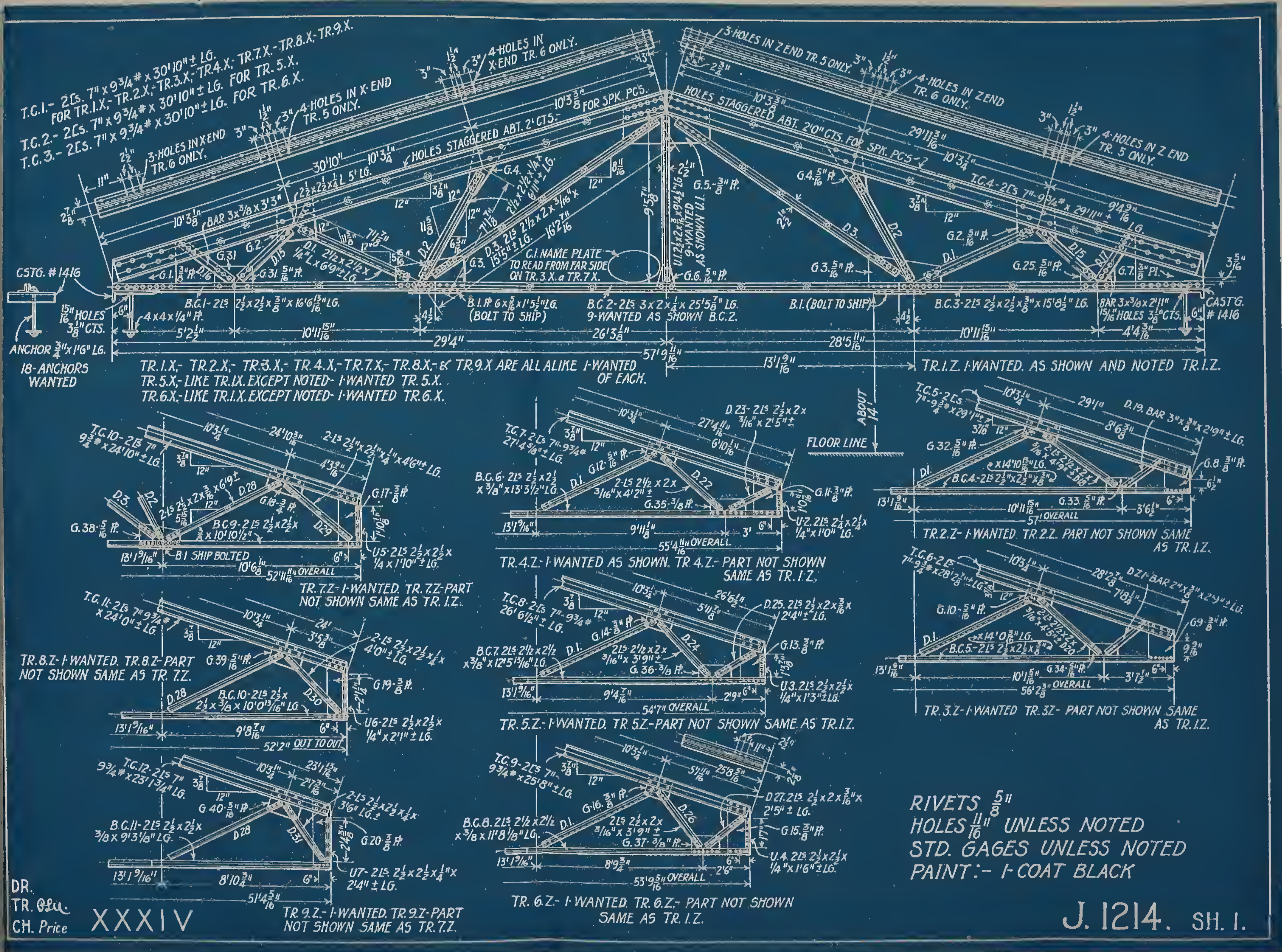
T.C.1.- 2[s. 7" x 9 3/4# x 30'10" ± LG. FOR TR.1.X; TR.2.X; TR.3.X; TR.4.X; TR.7.X; TR.8.X; TR.9.X.
T.C.2.- 2[s. 7" x 9 3/4# x 30'10" ± LG. FOR TR.5.X.
T.C.3.- 2[s. 7" x 9 3/4# x 30'10" ± LG. FOR TR.6.X.
3-HOLES IN X END TR.6 ONLY.
4-HOLES IN X-END TR.5 ONLY.
4-HOLES IN X-END TR.6 ONLY.
3-HOLES IN Z END TR.5 ONLY.
4-HOLES IN Z END TR.6 ONLY.
4-HOLES IN Z END TR.5 ONLY.
HOLES STAGGERED ABT. 2' CTS.- FOR SPK. PCS.
HOLES STAGGERED ABT. 2'0" CTS. FOR SPK. PC'S-Z
T.C.4-2[s 7"-9 3/4# x 29'11" ± LG.
BAR 3x3/8x3'3"
C.I. NAME PLATE TO READ FROM FAR SIDE ON TR.3.X & TR.7.X.
CSTG. #1416
CAST'G. #1416
B.C.1-2Ls 2 1/2 x 2 1/2 x 3/8" x 16'6 13/16" LG.
B.I. PL. 6x5/8x1'5 1/2" LG. (BOLT TO SHIP)
B.C.2-2Ls 3x2x1/4x25'5 7/8" LG. 9-WANTED AS SHOWN B.C.2.
B.I. (BOLT TO SHIP)
B.C.3-2Ls 2 1/2 x 2 1/2 x 3/8" x 15'8 1/2" LG.
BAR 3x3/8x2'11" 15/16" HOLES 3 1/8" CTS.
15/16" HOLES 3 1/8" CTS.
4x4x1/4" PL.
ANCHOR 3/4" x 1'6" LG.
18-ANCHORS WANTED
57'9 13/16"
TR.1.X,- TR.2.X,- TR.3.X,- TR.4.X,- TR.7.X,- TR.8.X,- & TR.9.X ARE ALL ALIKE 1-WANTED OF EACH.
TR.5.X,- LIKE TR.1X. EXCEPT NOTED- 1-WANTED TR.5.X.
TR.6.X,- LIKE TR.1.X. EXCEPT NOTED- 1-WANTED TR.6.X.
TR.1.Z. 1-WANTED. AS SHOWN AND NOTED TR.1.Z.
ABOUT 14'
FLOOR LINE
TR.7.Z- 1-WANTED. TR.7.Z-PART NOT SHOWN SAME AS TR.1.Z.
TR.4.Z.- 1-WANTED AS SHOWN. TR.4.Z.- PART NOT SHOWN SAME AS TR.1.Z.
TR.2.Z- 1-WANTED. TR.2.Z. PART NOT SHOWN SAME AS TR.1.Z.
TR.8.Z- 1-WANTED. TR.8.Z- PART NOT SHOWN SAME AS TR.7.Z.
TR.5.Z.- 1-WANTED. TR.5.Z.-PART NOT SHOWN SAME AS TR.1.Z.
TR.3.Z- 1-WANTED. TR.3.Z- PART NOT SHOWN SAME AS TR.1.Z.
TR.9.Z.- 1-WANTED. TR.9.Z.-PART NOT SHOWN SAME AS TR.7.Z.
TR.6.Z.- 1-WANTED. TR.6.Z.- PART NOT SHOWN SAME AS TR.1.Z.
RIVETS 5/8"
HOLES 11/16" UNLESS NOTED
STD. GAGES UNLESS NOTED
PAINT:- 1-COAT BLACK
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TR. Olu
CH. Price
XXXIV
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note placed at the left end of the spindle refers to a wringing fit. A wringing fit is one in which the parts are so fitted in dimensions as to have to be wrung, or twisted, together; some workmen interpret this to mean a fitting so snug that the pieces go together by lightly rapping them. In any case, it means a fit so snug that a little forcing is needed to slip the pieces together. The reader's attention is called to the limiting tolerances as expressed by the plus and minus signs and to the printed directions placed at the lower edge of the sheet which state that "unless otherwise specified, limits on this drawing are $\pm 0.005''$; dimensions of angles $\pm 1°$; and reamed or bored holes standard to $0.001''$ small". The term Woodruff key refers to the Whitney system of using Woodruff keys.

PLATE XXXIV

ROOF TRUSS

Plates XXXIV and XXXV are shown for the reason that the average shop man may be at times called upon to use such. Plate XXXIV shows a piece of structural work known as a roof truss. The word "truss" is shortened to *Tr.* on the blueprint. Steel structural work such as trusses, beams, girders, and columns is usually made up of angles, I beams, channels, plates, etc., riveted in such a manner as to get the desired construction. The various angles, channels, etc., are known as shapes and are hot rolled at the steel mills, straightened, and sold in open market.

The truss shown in Plate XXXIV is built up of angles of varying lengths riveted together and to flat pieces of plate known as gussets, or sometimes gusset plates. The several pieces of angles are given a letter symbol. In the roof truss shown the short pieces of angle steel used to tie the upper and lower parts together are symbolized by *D* and show on the blueprint as *D–1*, *D–2*, etc. The gusset plates are symbolized by *G* and appear on the blueprint as *G–1*, *G–2*, etc. In many cases a truss is too long to ship complete and has to be partly completed at the place used, or, as it is termed, in the field, and rivets driven after the truss leaves the shop are known as field rivets. The rivets which are to be driven while the truss is being built in the shop are indicated in the blueprint by small full circles, while the position of field rivets is shown on the angles by small white circular spots.

Noting what has been said relative to riveting, it will be observed that the blueprint shows that this truss is to be shipped in three sections and field riveted at the place where it is to be used.

A steel angle as rolled has the form shown in Fig. 2. The upright and the horizontal parts are known as the legs of the angle. In the truss shown, two of these angles about 30 feet 10 inches long are placed back to back to form the left half of the upper slant of the truss. In the same manner, two angles about 29 feet $11\frac{3}{16}$ inches long are placed back to back to form the right upper half of the truss. Previous to riveting the angles together for making each top slant, gusset plates as shown at *G–1*, *G–2*, *G–4*, *G–5*, and *G–7* are slipped between the angles and the whole is riveted together. In a like manner, the lower chord of the truss is riveted up. It will be noted that the gusset plates *G* are trimmed to come flush at the outer surfaces of the truss, but that they project into the inside of the truss a distance sufficient to allow the several short angles to be riveted to them. It will also be observed that when the angles are riveted together back to back with gusset plates, the surfaces of the legs of the angles are separated by an amount equal to the thickness of the gusset *G*. Any rivets driven through the angle plates at space points held apart by the gussets have small washers slipped into the crack, or space, between the angles, and the rivets are then set up through the washer. This is shown on the blueprint by means of a dotted circle around the space rivets. It must be noted that the bottom chord of the truss is not made up of single-length angles but is spliced at points about 15 feet $4\frac{1}{8}$ inches from each end of the truss. Where a splice such as this occurs in the bottom chord of a truss, it is strengthened by riveting a splice plate onto the bottom of the angles, covering and tying the splice.

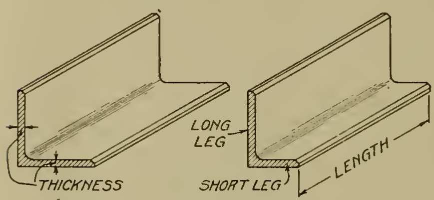
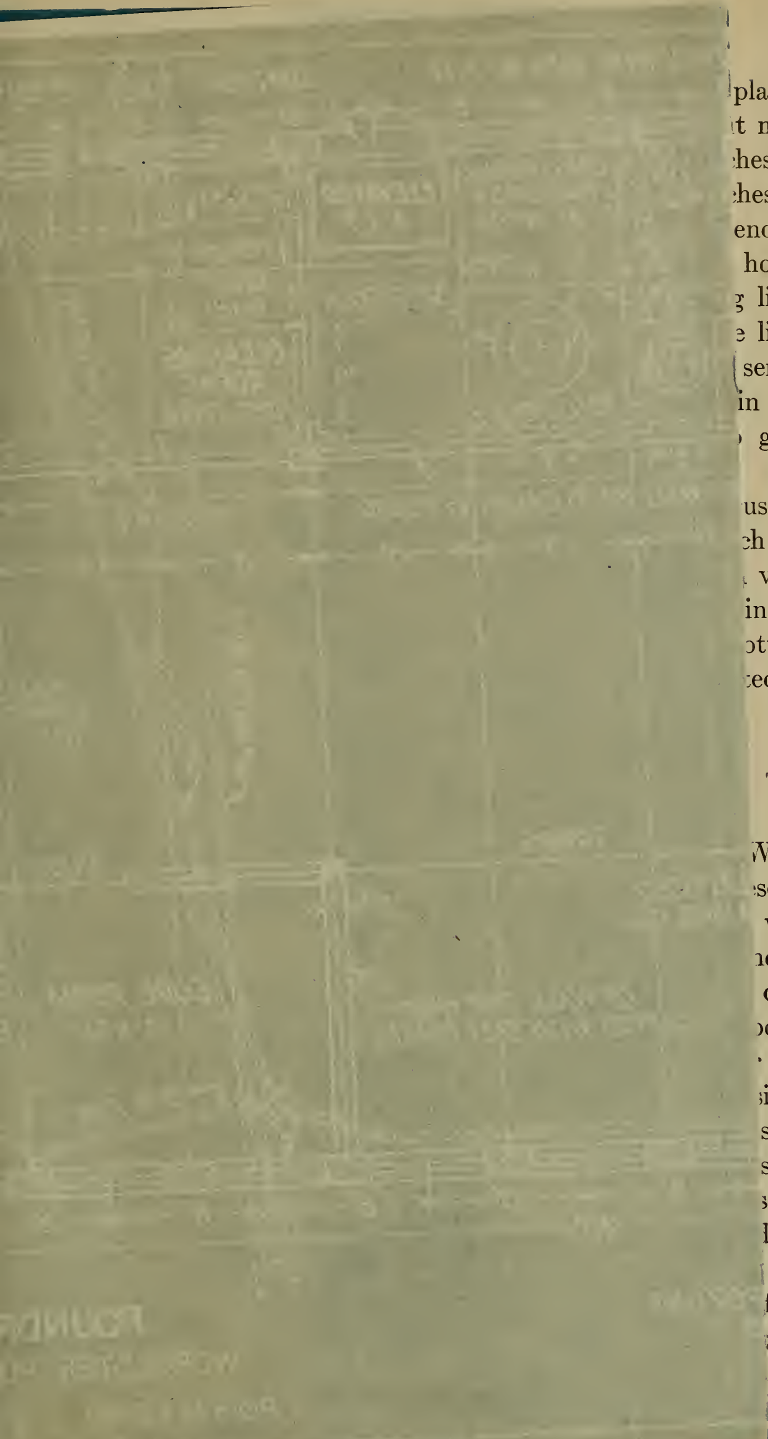


Fig. 2. Details of Angle Sections

Instead of giving in degrees and minutes the angle one piece makes with another, as is done in machine shop drawings, a small triangle is placed on the piece, as shown at the upper end of angle *D–3* and on its lower side. This means that the line



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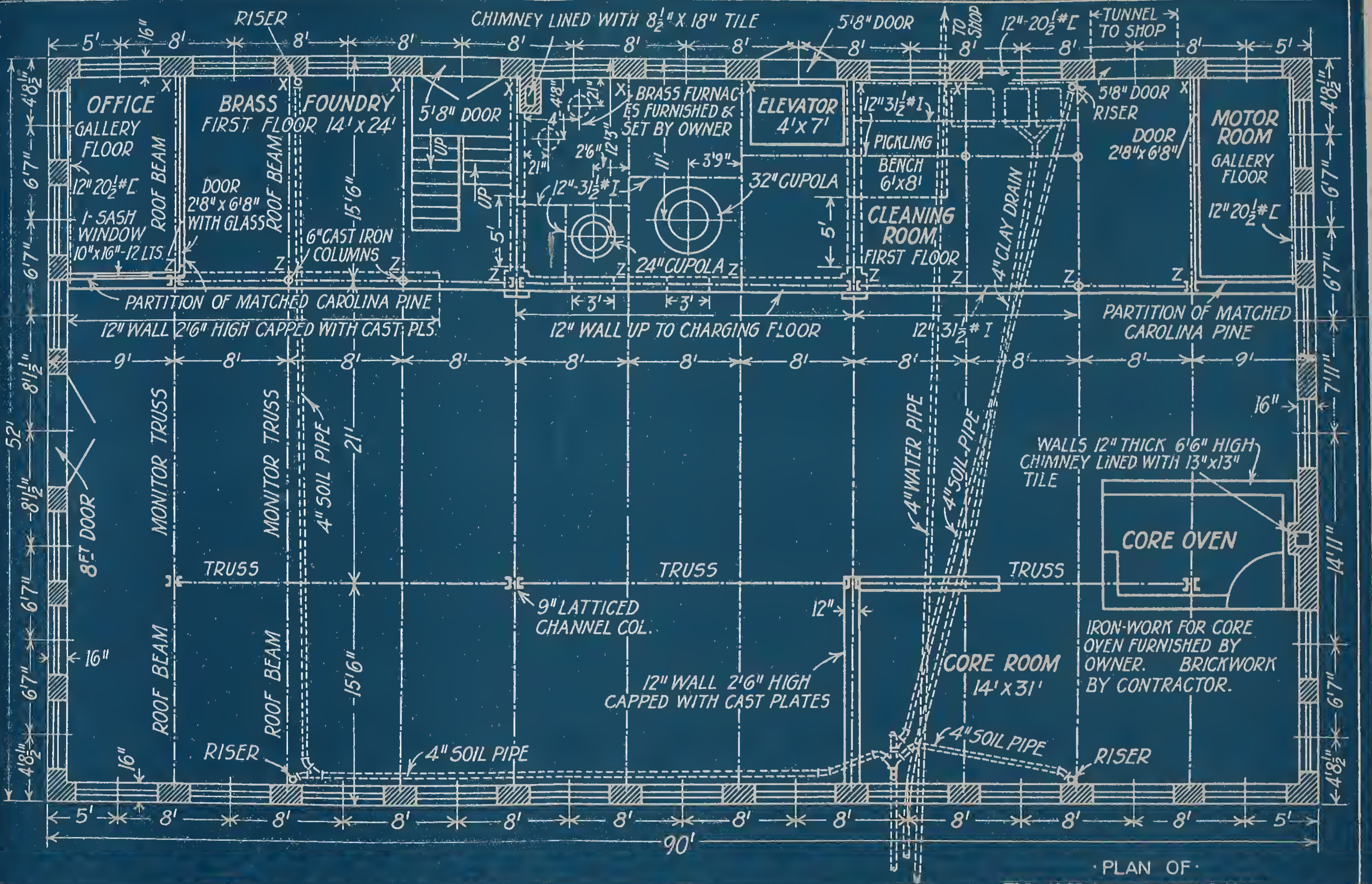

NOTE - AT X-Z ARE 12"-31½# I's SUPPORTING GALLERY AND CHARGING FLOORS.

XXXV

· PLAN OF ·

FOUNDRY BUILDING

WORCESTER POLYTECHNIC INSTITUTE

Plans by C.E. Dept. ¼-INCH = 1-FOOT *June 1902*

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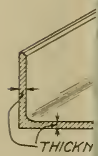

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on the gusset plate along which the rivet holes are to be placed rises from a base line $8\frac{11}{16}$ inches in 12 inches. The layout man accordingly measures off a base line on the gusset 12 inches in length and erects a perpendicular line on one end $8\frac{11}{16}$ inches in height. From this height he may scribe a line to the other end of the 12-inch base line and this is the gage line for the rivet holes. In all structural steel work the rivet holes are spaced along lines located a given distance from the back of the angle. These lines are termed *gage* lines and are not center lines in the usual sense. For example, in the view shown the reader will note that in the top member of the truss in the front view there are two gage lines and therefore two lines of rivets.

It will be observed that, while the top view of the truss is placed above the front view as in previous blueprints which we have studied, it parallels the slant of the truss. If a bottom view were given of this truss, it would show as if viewed from inside the truss; such a view is distinctly different from the bottom views already studied, and this point should be carefully noted in reading structural drawings.

PLATE XXXV

PLAN OF FOUNDRY BUILDING

Plate XXXV shows the plan of a foundry building. While the blueprint is more than ordinarily complete, it fairly represents such plans. The walls of the building are of brick and the windows are the prominent features of the walls. The reader should observe that the outside dimensions of the building, the door sizes, and the thickness of the walls are given; the columns, posts, interior walls, and partitions are located; the center-to-center distances are given; the foundry equipment is given and its position located on the plan; all stairways are indicated; and room measurements are given. Attention is called to the method of representing the windows by means of two parallel lines placed across the openings in the brick wall and to the method of showing the doors swung partly open. The plan shows a gallery floor along one side of the building. On this floor are located the office of the foreman, the charging floor for the cupolas, the motor room, etc.; the gallery floor is supported partly by the 9-inch latticed channel

columns and partly by a series of 6-inch round cast-iron columns. Three sets of doors are shown opening into the air and one opening into a tunnel to the shop. As a means of carrying off roof water and drainage from the pickling bed and cleaning room, a soil pipe line is shown. As most of this line of pipe is placed beneath the floor, it appears in the blueprint as a double dotted line. Two tile-lined chimneys are shown; one of these is for the brass furnace and one for the core oven. The core room is partly inclosed by means of a low wall capped with cast plates. The 8-foot door opens onto a driveway as do the two 5-foot 8-inch doors. These driveways and the street along the front of the building are not shown in the plan, but the street location could be assumed by the fact that the soil pipes, the clay drain, and the water pipes extend beyond the wall in a certain direction.

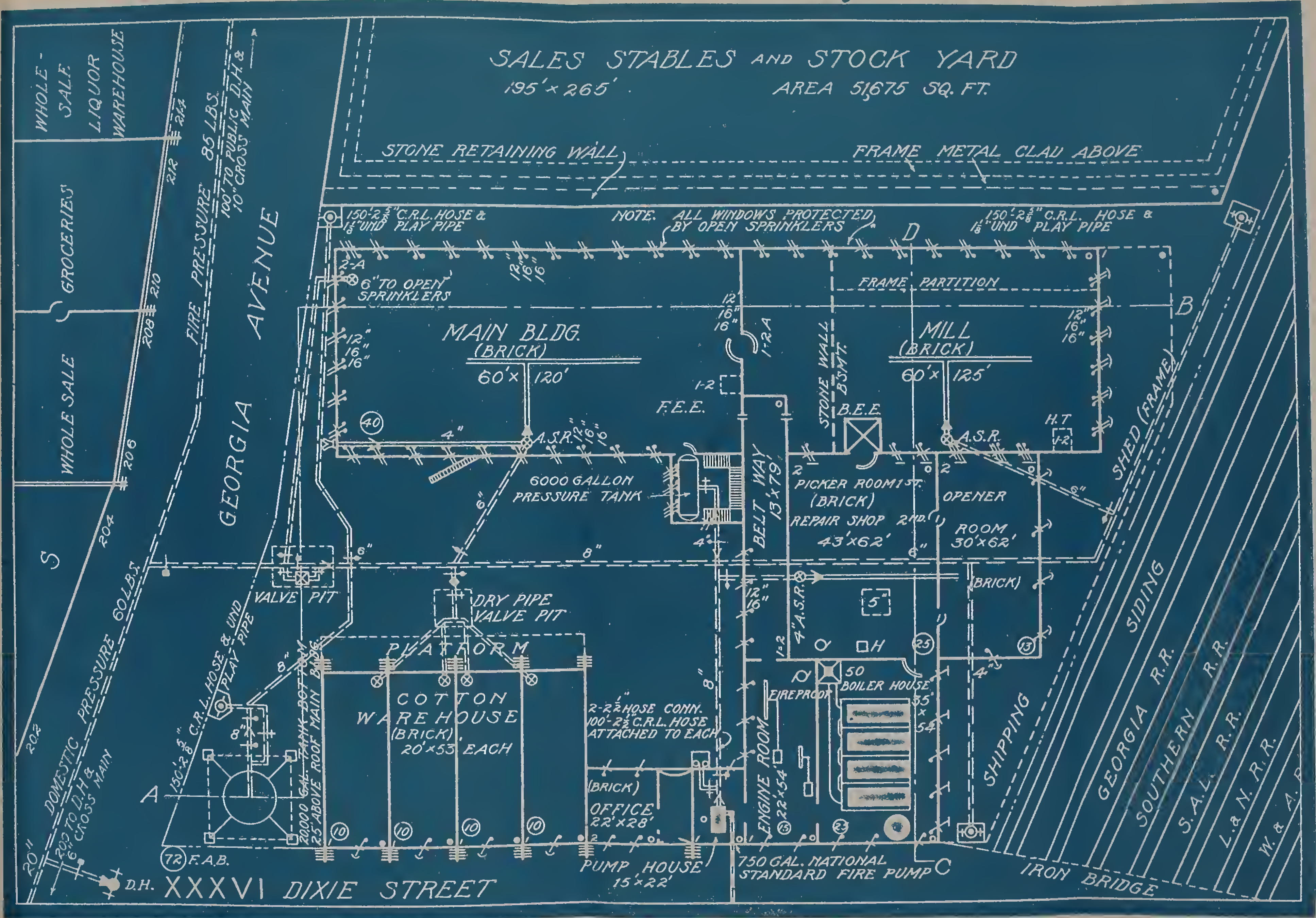
PLATE XXXVI

TYPICAL FIRE INSURANCE MAP

In fire insurance work the graphic description of a property has an important function; the custom is to show a plan or simple diagram of the insured properties, Plate XXXVI, adding certain simple devices for indicating such features of the building as may conveniently be described in this manner.

The map of a fire insurance risk gives the general location of the risk and its position relative to other risks. It also shows a scale drawing of the ground plan of the building, giving the dimensions, area, and, at the same time, a perfect idea of its general contour and the relation of the subdivisions of the building. By varying the thickness of the wall lines they are made to represent different kinds of walls. Unfinished or incomplete walls are represented by dotted lines; open spaces in the line indicate where the wall is interrupted or where a window opening occurs. Color is used to a large extent to indicate the different forms of construction; certain symbols, which follow in a measure the shapes of the things they represent, are used to shorten the description; and of course the use of initial letters is too well known to be more than mentioned. These symbols, it must be understood, are purely arbitrary but, having become established and recognized, they form the *symbol* language of the inspector and must be studied in a practical way in


SALE
GROCERIES
WHOLE SALE
DOMESTIC


SALES STABLES AND STOCK YARD
195'×265'
AREA 51,675 SQ. FT.
STONE RETAINING WALL
FRAME METAL CLAD ABOVE
WHOLE-SALE LIQUOR WAREHOUSE
GROCERIES
WHOLE SALE
FIRE PRESSURE 85 LBS.
100" TO PUBLIC D.H. & 10" CROSS MAIN
GEORGIA AVENUE
DOMESTIC PRESSURE 60 LBS.
20" TO D.H. & 6" CROSS MAIN
150'-2½" C.R.L. HOSE & 1⅛" UND. PLAY PIPE
NOTE. ALL WINDOWS PROTECTED BY OPEN SPRINKLERS
6" TO OPEN SPRINKLERS
MAIN BLDG. (BRICK)
60'×120'
F.E.E.
BELT WAY 13'×79'
STONE WALL BSMT.
B.E.E.
FRAME PARTITION
MILL (BRICK)
60'×125'
H.T.
A.S.R.
6000 GALLON PRESSURE TANK
PICKER ROOM 1ST. (BRICK)
REPAIR SHOP 2ND.
43'×62'
OPENER ROOM 30'×62'
SHED (FRAME)
VALVE PIT
DRY PIPE VALVE PIT
PLATFORM
COTTON WAREHOUSE (BRICK) 20'×53' EACH
2-2½" HOSE CONN.
100'-2½" C.R.L. HOSE ATTACHED TO EACH
(BRICK)
OFFICE 22'×28'
FIREPROOF
BOILER HOUSE 35'×54'
ENGINE ROOM 22'×54'
150'-2½" C.R.L. HOSE & UND. PLAY PIPE
20,000 GAL. TANK BOT. 25' ABOVE ROOF MAIN BLDG.
F.A.B.
D.H.
XXXVI DIXIE STREET
PUMP HOUSE 15'×22'
750 GAL. NATIONAL STANDARD FIRE PUMP
IRON BRIDGE
SHIPPING
SIDING
GEORGIA R.R.
SOUTHERN R.R.
S.A.L. R.R.
L. & N. R.R.
W. & A. R.R.

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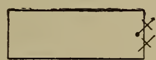
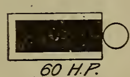
order to be recognized when presented. A few of these symbols and their description are given to convey some idea of the manner in which the map may be interpreted.

A solid thick line ——— represents an independent wall. A solid thin line represents a party wall. A distinct break in the line representing a division or side wall —— —— indicates an opening made by a doorway or arch. A small curved line  or a short line at right angles indicates the presence of a fire door, the auxiliary line being placed on the side of the wall the door is on. An auxiliary line on each side indicates a fire door on each side of the walls. A double curved line  is used to represent a standard fire door.  A little black dot on the inside end of a window line indicates a window opening on that side of two adjoining walls. If the black dot is missing, it means that there is no window on this floor. A single curve over the end of the window line represents a non-standard fire shutter. A straight line indicates the presence of wire glass. The initial H within a hollow square is used to represent a hoistway or hatch. 

The letter S within a hollow square is used to represent a stairway. A stairway is also represented by a rectangular outline crossed by straight lines supposed to represent the stair steps. A solid black oblong figure represents a horizontal boiler, while a solid black circle represents a vertical boiler. A thin line around the solid black oblong figure 

and the margin colored in red represents a horizontal steam boiler which is bricked in. A small thin-lined circle with diagonals and a black dot at their intersection 

indicates an automatic sprinkler riser. A sprinkler pressure tank is represented thus .

Plate XXXVI is a copy of a map issued in connection with the adoption of these symbols by the Fire Underwriters Uniformity Association and brings into use practically all the symbols needed.

MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA
Dean and Dean, Architects, Chicago

MECHANICAL DRAWING

PART I

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is a method of showing graphically the minute details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way of placing ideas and calculation on record. A brief inspection of an accurate, well-executed working drawing gives a better idea of a machine than a lengthy written or verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. Thorough training in this important subject is necessary to the success of every-one engaged in mechanical work.

The draftsman is dependent for his success, to a certain extent, upon the quality of the instruments and materials which he uses. As a beginner, he will find a cheap grade of instrument sufficient for his needs; but after he has become expert, it will be necessary for him to procure those of better construction and finish to enable him to do accurate work. It is a better plan to purchase the well-made instruments, if possible, at the start.

INSTRUMENTS AND MATERIALS

Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manila paper is frequently used on account of its toughness and strength, for these drawings are likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong; should have uniform thickness and surface; should stretch evenly and lie smoothly when stretched

or when ink or colors are used; should neither repel nor absorb liquids; and should allow considerable erasing without spoiling the surface It is, of course, impossible to find all of these qualities in any one paper, as great strength cannot be combined with fine surface. However, a kind should be chosen which combines the greatest number of these qualities for the given work. Of the higher grades of papers, Whatman's are considered by far the best. This paper, either side of which may be used, is made in three grades: the *hot pressed*, which has a smooth surface and is especially adapted for pencil and very fine line drawing; the *cold pressed*, which is rougher than the hot pressed, has a finely grained surface, and is more suitable for water color drawing; and the *rough*, which is used for tinting. For general work, the cold pressed is the best as erasures do not show as plainly on it, but it does not take ink as well as the hot pressed.

Whatman's paper comes in sheets of standard sizes as follows:

Cap	13×17 inches	Imperial	22×30 inches
Demy	15×20 "	Atlas	26×34 "
Medium	17×11 "	Double Elephant . .	27×40 "
Royal	19×24 "	Antiquarian . . .	31×53 "
Super-Royal . . .	19×27 "		

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. First fasten the upper left-hand corner and then the lower right, pulling the paper taut. The other two corners are then fastened, and a sufficient number of tacks placed along the edges to make the paper lie smoothly. For very fine work, however, it is better to stretch the paper and glue it to the board. Turn up the edges of the paper all the way round—the margin being at least one inch—then moisten the surface of the paper by means of a sponge or soft cloth, and spread paste or glue on the turned-up edges. After removing all the surplus water on the paper, press the edges down on the board, commencing at one corner and stretching the paper *slightly*—if stretched too much it is liable to split in drying. Place the drawing board in a horizontal position until the paper is dry, when it will be found to be as smooth and tight as a drum head.

Drawing Board. The drawing board, Fig. 1, is usually made of well-seasoned and straight-grained soft pine, the grain running lengthwise of the board. Each end of the board is protected by a

side strip—$1\frac{3}{4}$ to 2 inches in width—whose edge is made perfectly straight for accuracy in using the T-square. Frequently the end

Fig. 1. Drawing Board

pieces are fastened by a glued matched joint, nails or screws. Two cleats on the bottom, extending the whole width of the board, will reduce the tendency to warp. Drawing boards are made in sizes to accommodate the sizes of paper in general use.

Thumb Tacks. Thumb tacks are used to fasten the paper to the drawing board. They are usually made of steel, pressed into shape—as in the cheaper grades—or with heads of German silver, the points being screwed and riveted to them. For most work, draftsmen use small one-ounce copper or iron tacks, as they are cheap and can be forced flush with the drawing-paper, thus offering no obstruction to the T-square.

Pencils. Lead pencils are graded according to their hardness, the degree of which is indicated by the letter H—as HH, 4H, 6H, etc. For general use a lead pencil of 5H or 6H should be used, although a softer 4H pencil is better for making letters, figures, and points. The hard lead pencil should be sharpened as shown in Fig. 2 so that in penciling a drawing the lines may be made very fine and light. The wood is cut away so that about $\frac{1}{4}$ or $\frac{1}{2}$ inch of lead

projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file, and the corners slightly rounded. In drawing the lines the draftsman should place the chisel edge against the T-square or triangle, thus enabling him to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, so as to make the lines somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge for the compasses as well as the pencil.

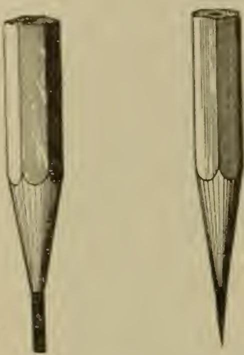


Fig. 2. Pencil Sharpened to a Chisel Point

In using a very hard lead pencil a light pressure should be used as otherwise the chisel edge will make a deep impression in the paper which cannot be erased.

Erasers. What little erasing is necessary in making drawings, should be done with a soft rubber. To avoid erasing the surrounding work some draftsmen use a card in which a slit is cut about 3 inches

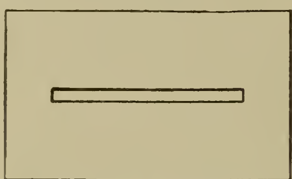


Fig. 3. Erasing Shield

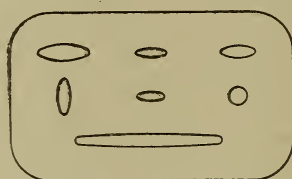


Fig. 4. Metal Erasing Shield

long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide, Fig. 3. An erasing shield of thin metal, Fig. 4, is also very convenient, especially in erasing letters. For cleaning drawings when they are completed, a sponge rubber or a preparation called "art gum" may be used, but in either case care should be taken not to make the lines dull by too hard rubbing.

T-Square. The T-square, which gets its name from its general shape, consists of a thin straight-edge, the *blade*, with a short piece, the *head*, fastened at right angles to it, Fig. 5. T-squares are usually made of wood, the pear and maple woods being used in the cheaper grades, and the harder woods, like mahogany, with protecting edges

of ebony or celluloid, Fig. 6, in the more expensive instruments. The head is designed to fit against the edge of the drawing board, allowing the blade to extend across the surface of the board. It is

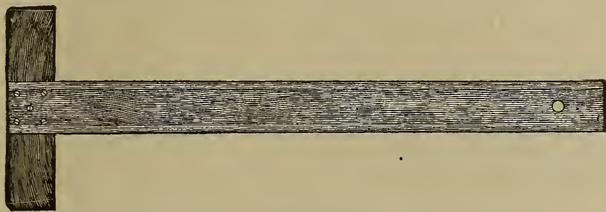


Fig. 5. Common T-Square

desirable to have the blade of the T-square make a right angle with the head, but this is not absolutely necessary, if the head is always placed against the left-hand edge of the board, for the lines drawn

Fig. 6. Mahogany-Bound T-Square

with the T-square will then be referred to one edge of the board only, and if this edge is straight, the lines will be parallel to each other.

T-squares are sometimes provided with swiveled heads as it is frequently very convenient to draw lines parallel to each other which are not at right angles to the left-hand edge of the board. To use the T-square in drawing parallel horizontal lines,* place the head of the T-square in contact with the left-hand edge of the board, Fig. 7, and draw the pencil along the *upper edge* of the blade at each new position of the T-square. Only the upper edge should be used as the

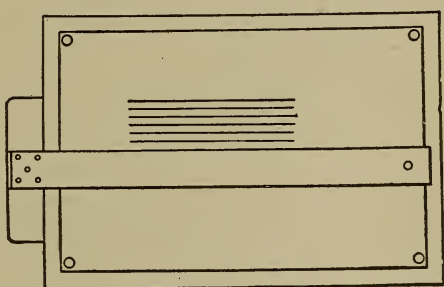


Fig. 7. Drawing Parallel Lines

* See page 23.

two edges may not be exactly parallel and straight. In trimming drawings or cutting the paper from the board, always use the *lower edge* of the T-square so that the upper edge may not be made untrue.

For accurate work it is absolutely necessary that the upper edge of the T-square be exactly straight. To test the straightness of the edge two T-squares may be placed together as shown in Fig. 8. However, a lack of contact such as shown in the figure does not prove which edge is crooked, and for this determination a third blade must be used and tried with the two given T-squares successively.

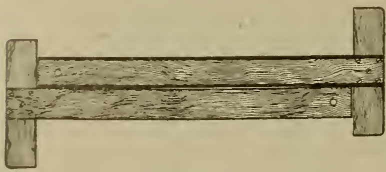


Fig. 8. Testing the Edge of T-Square

Triangles. Triangles are made of various substances such as wood, rubber, celluloid, and steel. Wooden triangles are cheap but are likely to warp out of shape; rubber triangles are frequently used, and are, in general, satisfactory; celluloid triangles are extensively used on account of their transparency, which enables the draftsmen to see the work already done even when covered with the triangle.

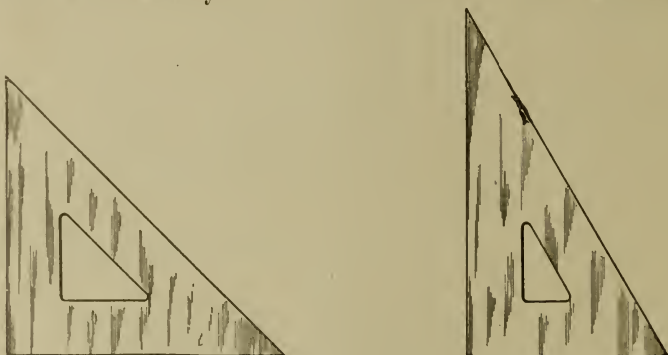


Fig. 9. 45° and 30° – 60° Triangles

In using a rubber or celluloid triangle take care that it lies perfectly flat and is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle

measuring about 4 inches on a side will be found useful. Every draftsman should have at least two triangles, one having two angles of 45 degrees and one right angle; and the other having angles of 30, 60, and 90 degrees, respectively, Fig. 9.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of

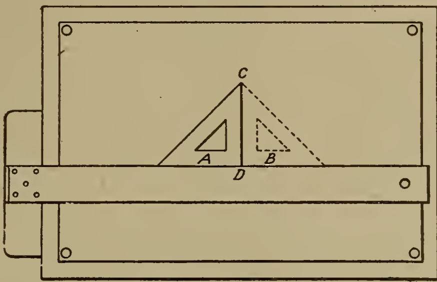


Fig. 10. Testing a Right Angle (45° Triangle)

the right angle of a triangle, place the triangle with the lower edge resting on the T-square in position *A*, Fig. 10. Now draw the line *C D*, which, if the triangle be true, will be perpendicular to the edge of the T-square. Transfer the triangle to position *B*, and if the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle will exactly coincide with the line *C D*.

To test the accuracy of the 45-degree angles place the triangle with the lower edge resting on the working edge of the T-square,

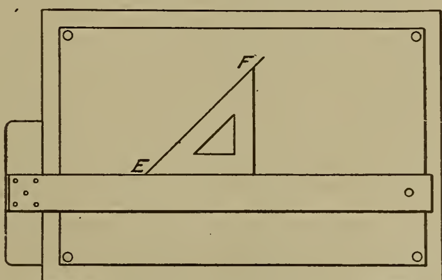


Fig. 11. Testing 45° Angle (45° Triangle)

and draw the line *E F*, Fig. 11. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

Triangles are used in drawing lines at right angles to the T-square, Fig. 12, and at an angle with the horizontal, Fig. 13. If it is desired to draw a line through the point *P*, Fig. 14, parallel to a given

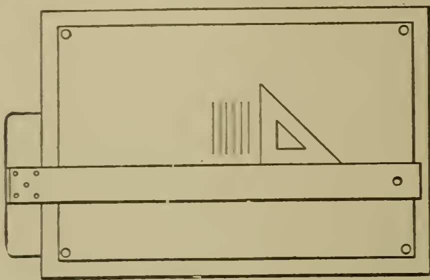


Fig. 12. Drawing Vertical Parallel Lines

line *E F*, two triangles should be used. First, place triangle *A* with one edge coinciding with the given line. Now take triangle *B* and place one of its edges in contact with the bottom edge of triangle *A*. Holding triangle *B* firmly with the left hand, slide triangle *A* to the right or to the left until its edge reaches the point *P*. The line *M N* may then be drawn passing through the point *P*. In place of the triangle *B* any straight-edge such as a T-square may be used.

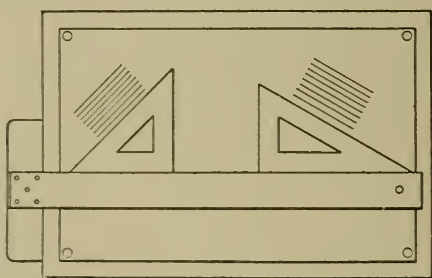


Fig. 13. Drawing Parallel Lines at an Angle with the Horizontal

A line may be drawn through a point, perpendicular to a given line by means of triangles as follows: Let *E F*, Fig. 15, be the given line, and let the point be *D*. Place the longest side of triangle *A* so that it coincides with the line *E F*. Place the other triangle (or any straight-edge) in the position of the triangle *B;* then holding *B* with the left hand, place the triangle *A* in the position *C*, so that the longest side passes through the point *D*. A line may then be drawn through the point *D* perpendicular to *E F*.

In previous figures it has been shown how lines may be drawn making angles of 30, 45, 60, and 90 degrees with the horizontal.

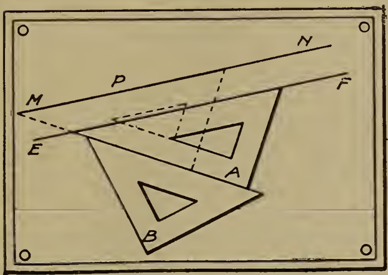


Fig. 14. Drawing a Line Parallel to a Given Line

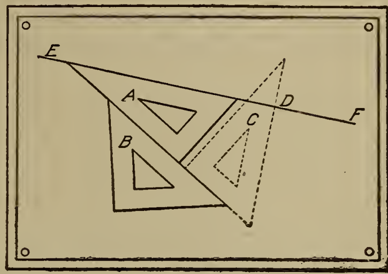


Fig. 15. Drawing a Line Perpendicular to a Given Line

It is possible to draw lines forming angles of 15 and 75 degrees by placing the triangles as shown in Fig. 16.

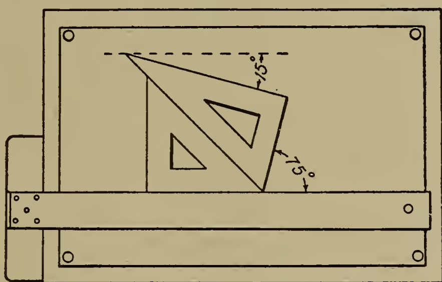


Fig. 16. Drawing Angle of 15° and 75°

By the use of the triangles and T-square almost any line may be drawn. Suppose it is desired to draw a rectangle having one side

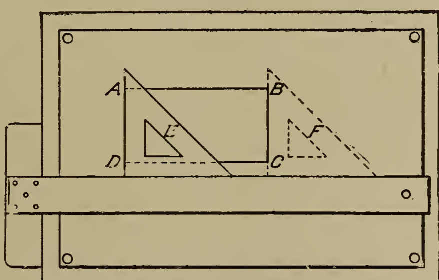


Fig. 17. Drawing a Rectangle with T-Square and Triangle

horizontal. First draw by means of the T-square the sides *A B* and *D C* horizontal and parallel, Fig. 17. Now place one of the

triangles on the T-square and in positions E and F draw the vertical lines $D\ A$ and $B\ C$.

If the rectangle is to be drawn in some other position on the board, as shown in Fig. 18, place the 45-degree triangle F so that the longest edge is in the required direction of the side $D\ C$. Now, hold the triangle F in position and place another triangle in position H. By holding H in position and sliding triangle F, the sides $A\ B$ and $D\ C$ may be drawn. To draw the sides $A\ D$ and $B\ C$ change triangle F to position E and repeat the process.

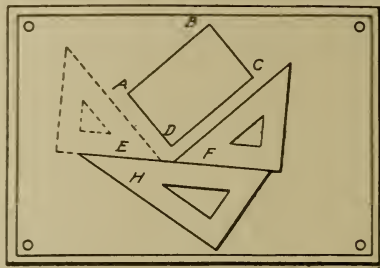


Fig. 18. Rectangle Drawn with Triangles

Compasses. Compasses are used for drawing circles and arcs of circles. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver, as it does not soil the hands, has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the softness of the metal they do not wear well.

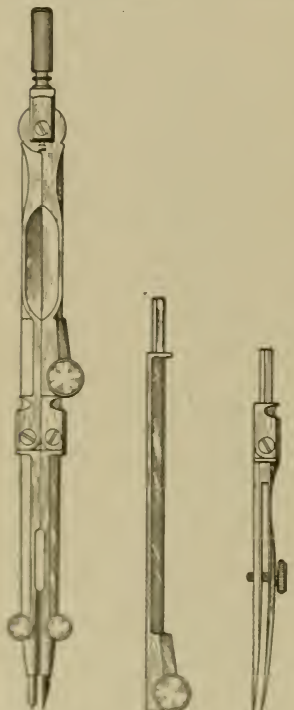


Fig. 19. Compasses and Attachments

The compasses are made in the form shown in Fig. 19 and are provided with pencil and pen points. Fig. 20 shows the compass in position for drawing circles. One leg has a socket into which the shank of the pencil or pen mounting may be inserted. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point projects through a piece of round steel wire with a square shoulder at one or both ends.

In some instruments the joints are held in position by lock nuts,

made of thin disks of steel, with notches for using a wrench or forked key. Fig. 21 shows the detail of the joint of a high grade instrument. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, yet gives the proper stiffness. The flat surface of one leg is faced with steel, the other with German silver, so that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dirt and to prevent rusting of the steel face.

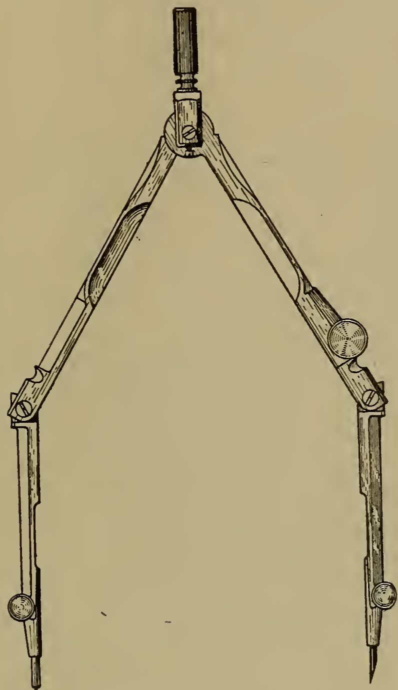


Fig. 20. Compasses Set for Drawing Circles

The details of the socket are shown in Fig. 22, Fig. 23, and Fig. 24; in some instruments the shank and socket are pentagonal, Fig. 22, the shank entering the socket loosely, and being held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 23 is shown a round shank, the shank having a flat top, with a set screw to hold the shank in position. A still better form of socket is shown in Fig. 24, the hole being circular and tapered. The shank fits accurately into the split socket and is clamped by a screw on the side; it is held in perfect alignment by a small steel key.

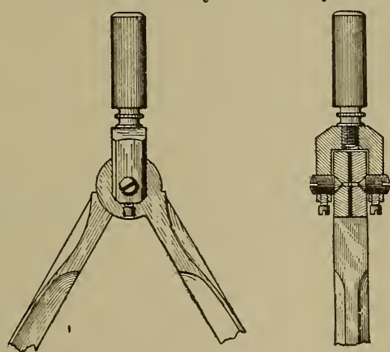


Fig. 21. Details of Compass Joint

Both legs of the compass are jointed in order that the lower part

of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In penciling circles it is not as necessary that the pencil should be kept vertical;

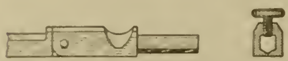


Fig. 22. Pentagonal Shank and Socket

Fig. 23. Circular Shank and Socket

it is a good plan, however, to learn to use them in this way both in penciling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

Fig. 24. Circular Socket with Set Screw

Fig. 25. Dividers

In removing the pencil or pen attachment from the compass it should be pulled out straight in order to avoid enlarging the socket, and thus rendering the instrument inaccurate. For drawing large circles use the lengthening bar, Fig. 19, steadying the needle point with one hand and describing the circle with the other.

Dividers. Dividers, which are similar to compasses, are used to lay off distances on the drawing, either from a scale or from other parts of the drawing, Fig. 25. They are also used for dividing a line into equal parts. To do this turn the dividers in the opposite direction each time, *i. e.*, move the point alternately to the right and to the left. The points of the dividers should be very sharp so that the holes made in the paper will be small, thus assuring accurate spacing. Compasses may be used as dividers by substituting for the pencil or pen point an extra steel point, usually furnished with the instrument. In place of dividers many draftsmen use a *needle point*. The needle, with the eye-end broken off, is forced into a handle of soft pine, making a convenient instrument for marking line intersections and distances.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy and the leverage of the long leg is too great to allow small circles to be drawn accurately. For this reason the bow compasses, Figs. 26 and 27, should be used on all arcs and circles having a radius of less than $\frac{3}{4}$ inch, such as those which represent boiler tubes and bolt

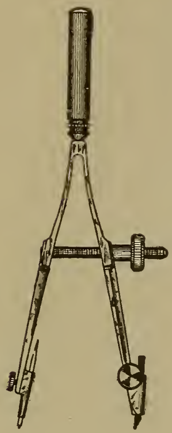


Fig. 26. Bow Pencil

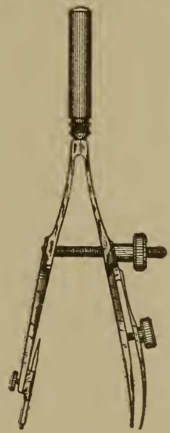


Fig. 27. Bow Pen

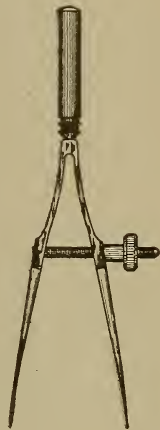


Fig. 28. Bow Divider

holes. When small circles are drawn, the needle point must be adjusted to the same length as the pen or pencil point. If a considerable change in radius is made, press the points together before turning the nut so as to prevent wear in the screw threads. The bow dividers, Fig. 28, replace the ordinary dividers in small work and have the advantage of a fixed adjustment.

Drawing Pen.* For drawing straight lines and curves that are not arcs of circles, the line pen—sometimes called the *ruling pen*—is

Fig. 29. Drawing Pen

used, Fig. 29. The distance between the pen points, which regulates the width of line to be drawn, is adjusted by the thumb screw, and the blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

*See page 22.

The pen should not be dipped in the ink but should be filled by means of a common steel pen or quill, to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work wipe the pen with chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper, in order that the line may be smooth. The pen is usually inclined slightly in the direction in which the line is drawn and should touch the triangle or T-square lightly so as not to press the blades together and thereby change the width of the line; the pen must not be tipped outward, however, as the danger of blotting is greatly increased when the line is drawn so close to the guide.

Sharpening the Drawing Pen. When it is impossible to make a smooth line with the drawing pen, it should be sharpened. Screw the blades together and grind them to a parabolic shape by drawing the pen back and forth over a small, flat, close-grained oilstone. This process, of course, makes the blades dull but insures their being of the same length. Now separate the points slightly and rub one of them on the oilstone, keeping the pen at an angle of from 10° to 15° with the face of the stone, and giving it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After one point has become fairly sharp, grind the other in a similar manner, grinding always on the *outside* of the blades and removing the burr from the inside with leather or pine wood. Test the pen by filling with ink and drawing several lines. Unless the lines are smooth, the grinding must be continued.

Ink. India ink is always used for drawing as it makes a permanent black line; it is obtainable in solid stick or liquid form. The liquid form is much more convenient but contains acid which corrodes steel and makes it necessary to keep the pen perfectly clean.

To prepare the ink in stick form for use, put a little water in a saucer and place one end of the stick in it; then by a twisting motion grind enough ink to make the water black and slightly thickened. Now draw a heavy line on a sheet of paper and if after drying the line has a grayish appearance, more grinding is necessary. Wipe the stick dry after using to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily a second time, however, if covered it will keep for two or three days.

Scales. The scales used for obtaining measurements on drawings are made in several forms, the most convenient being the *flat*, with beveled edges, and the *triangular*. The scale is usually graduated for a distance of 12 inches. The triangular scale, Fig. 30, has six

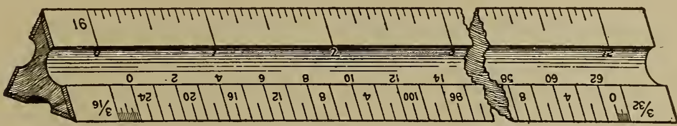


Fig. 30. Triangular Scale

surfaces for different graduations, and the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two; thus drawings are made full size, $\frac{1}{2}$ size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects and civil engineers, and for measuring indicator cards.

The scale should never be used as a substitute for the triangle or T-square in drawing lines.

Protractor. The protractor, an instrument used for laying off and measuring angles, is made of steel, brass, horn, or paper. When

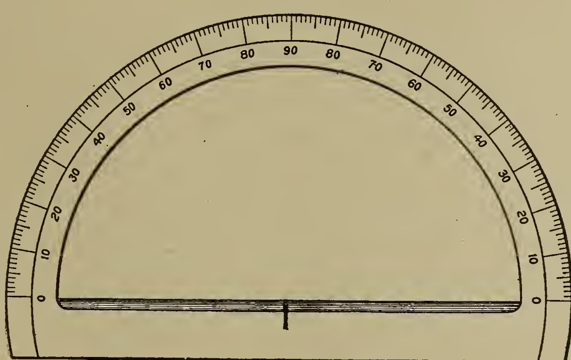


Fig. 31. Protractor

made of metal the central portion is cut out, Fig. 31, so that the draftsman may see the drawing. The outer edge is divided into degrees

and tenths of degrees. To lay off the required angle—use a very sharp, hard pencil in order that the measurements may be accurate—place the protractor so that the two zero marks are on the given line, produced, if necessary, and the center of the circle is at the point through which the desired line is to be drawn.

Irregular Curve. One of the conveniences of a draftsman's outfit is the *French* or *irregular curve,* which is used for drawing curves other than arcs of circles, with either pencil or line pen. This instrument, which is made of wood, hard rubber, or celluloid—celluloid being the best—is made in various shapes, one of the most common being shown in Fig. 32. Curves drawn with an irregular curve are called *free hand curves.*

To draw a curve through a series of located points find that position of the irregular curve that passes through three points,

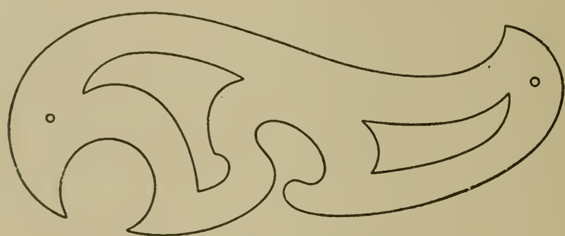


Fig. 32. Typical Irregular Curve

say, and draw the line through them, Fig. 33. Now shift the curve so as to include a part of the curve already drawn and two or three more points. Draw the curve through these points, continuing this process until the curve is completed. If, at each new setting, the line is not carried quite as far as the coincidence of the irregular curve would permit, a smoother curve will result. It frequently facilitates the work and improves its appearance to draw a pencil curve free hand through the points and then use the irregular curve, taking care that it always fits at least *three* points. In inking the curve, the blades of the pen must be kept tangent to the curve. For certain kinds of work, irregular curves of plastic metal are sometimes used to fit exceptionally erratic curves.

Beam Compasses. The ordinary compasses are suitable for drawing circles up to 8 or 10 inches diameter. For larger circles beam compasses are provided. The two parts called *channels*

which carry the pen or pencil and the needle point are clamped to a wooden beam at a distance equal to the radius of the circle. The

Fig. 33. Method of Using Irregular Curve

thumb nut underneath one of the channel pieces makes accurate adjustment possible.

LETTERING

No mechanical drawing is finished unless all headings, titles, and dimensions are lettered in plain, neat type. Many drawings are accurate, well-planned, and finely executed but do not present a good appearance because the draftsman did not think it worth while to letter carefully. Lettering requires time and patience especially for the beginner; and many think it a good plan to practice lettering before commencing drawing. Poor writing need not necessarily mean poor lettering, for good writers do not always letter well.

In making large letters for titles and headings it is often necessary to use drawing instruments and mechanical aids, but small letters, such as those used for dimensions, names of materials, dates, etc., **should be made free-hand.**

Forming. The student is apt to think that lettering is a form of mechanical drawing, that the use of the straight-edge is the principal operation, and that letters, forms, and the spaces between are to be figured out by measurement. On the contrary, lettering is design, and the draftsman so distributes the letters in the spaces arranged for them as to make a combination that will be pleasing to the eye. The requirements for a good design are simplicity and uniformity. These are acquired by accuracy in detail and by good judgment and taste, as no practical rules can be followed which will

invariably produce the same result. Letter forms are, to a certain extent, standard. The lettering for a title is usually done very carefully and accurately, while practically all of the other lettering on a drawing is done rapidly and in a simple style. To develop a letter use the same method of procedure as in drawing a straight line between two points. First, draw the guide lines rather carefully and then block out the general form of the letter by a series of short strokes of the pencil. Continue this method, straightening the lines and rounding the curves of the latter until its form is satisfactory.

Spacing. The spacing of the letters is very important and is best obtained by the unaided eye just as are the proportions of the letters. Care must be taken to allow a clear distance between letters, the space varying according to the combination. For instance, such letters as *A*, *V*, and *W* spread more at one part than at another and therefore do not fill the space completely. Of course, when the distance between letters is large any such irregularities will not be noticeable. The best method for obtaining good space values is by sketching in the letters roughly and then bringing them to a good appearance by correction and adjustment The first results are, of course, unsatisfactory, but after the eye and hand have become trained, great improvement will be noticed. A simple aid to this development will be found in the use of a piece of cardboard with the widths of the enclosing rectangles or parallelograms of the different letters marked on its edge, by which the spacing made by the eye may be checked.

Inking. In practical work most of the lettering is penciled in and then finished in ink. As faults in letters which may not be noticed in the penciled work stand out clearly after inking, it is not advisable to ink in the penciled letter accurately, but rather to improve upon it.

For lettering free-hand, use a pen that will make the full weight of line desired without much pressure, holding it squarely on the paper and directly in front. A new pen, which is apt to give too fine a line, may be remedied by scratching a little on a rough surface. If a pen is kept clean and all hardened ink removed so that the nibs are not spread, the pen will last a long time. A coarser pen must be used on rough than on smooth paper.

To remove a faulty line or a blot, let the ink dry thoroughly,

then with a sand rubber, erase the spot carefully, rubbing around it, as well. Clean the sand out of the surface with a pencil eraser and finally polish down with a piece of ivory or smooth wood. Pencil in the parts erased as if doing the work for the first time and again ink in, using special care, as the ink is more likely to spread on an erased surface than anywhere else.

Style. There are many styles of letters used by draftsmen, but almost any neat letter free from ornamentation is acceptable in regular practice. For titles, large Roman capitals are preferred, although Gothic and black letters also look well and are much easier to make. The vertical and inclined or italicized Gothic capitals shown in Fig. 34 and Fig. 35, are neat, plain, and easily made. This

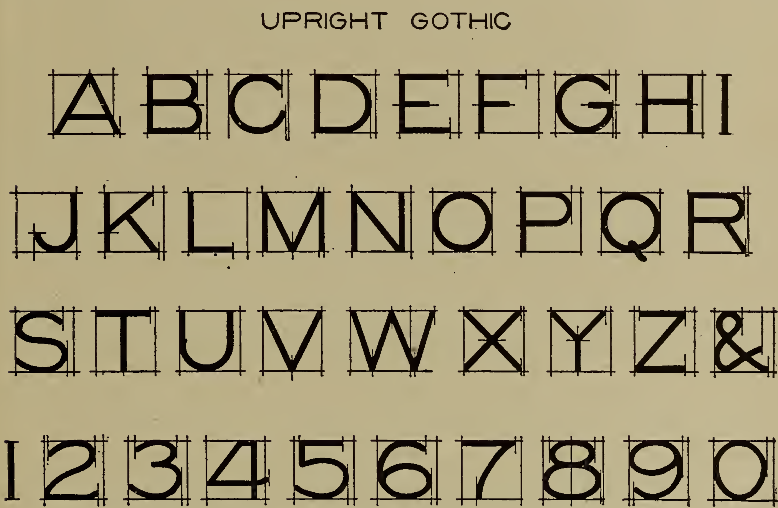


Fig. 34. Upright Gothic Capitals

latter style possesses the advantage over the vertical type in that a slight difference in inclination is not apparent.

The curves of the inclined Gothic letters such as those in *B*, *C*, *G*, *J*, etc., are somewhat difficult to make free-hand, especially if the letters are about one-half inch high. In the alphabet, Fig. 36, the letters are made almost wholly of straight lines, the corners only being curved.

The first few plates of this work will require no titles, the only lettering being the student's name, the date, and the plate number

which will be done in inclined Gothic capitals. Later the subject of lettering will again be taken up in connection with titles and headings for drawings which show the details of machines.

To make the inclined Gothic letters, first draw two parallel lines $\frac{5}{32}$ inch apart to mark the height for the letters of the date, name,

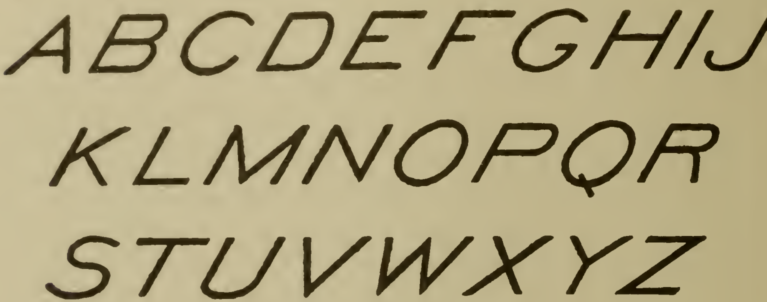


Fig. 35. Inclined Gothic Capitals

and plate number. This is the height to be used on all plates throughout this work, unless other directions are given. When two sizes of letters are used, the smaller should be about two-thirds as high as the larger. The inclination of the letters should be the same for all,

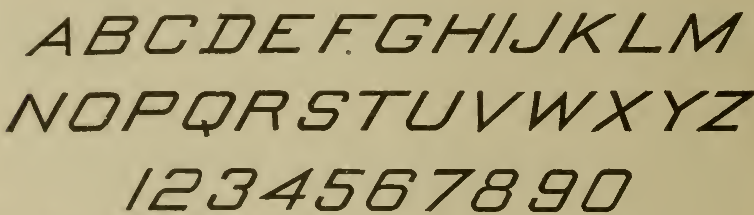


Fig. 36. Inclined Gothic Capitals— Straight Lines with Curved Corners

and as an aid to the beginner, light pencil lines may be drawn about $\frac{1}{4}$ inch apart, forming the proper angle with the parallel lines already drawn; this angle is usually about 70°, but if a 60° triangle is at hand, it may be used in connection with the T-square as shown in Fig. 38.

Capital letters such as *D*, *E*, *F*, *L*, *Z*, etc., should have their top and bottom lines coincide with the horizontal guide lines, as otherwise the work will look uneven. Letters, of which *C*, *G*, *O*, and *O* are types, may be formed of curved or straight lines. If made of

curved lines, their height should be a little greater than the guide lines to prevent their appearing smaller than the other letters. In this work they may be made of straight lines with rounded corners as such letters are easily constructed and may be made of standard height.

To construct the letter *A*, use one of the 60° lines as a center line. Then from its intersection with the upper horizontal line drop a perpendicular to the lower guide line. Draw another line from the vertex meeting the lower guide line at the same distance on the other side of the center line. The cross line of the *A* should be a little below the center. The *V* is an inverted *A* without the cross line. For the letter *M*, the side lines should be parallel and about the same distance apart as the guide lines. The side lines of the *W* are *not* parallel but are farther apart at the top. The *J* is not quite as wide as such letters as *H*, *E*, *N*, *R*, etc. To make a *Y*, use the same spread as in making a *V* but let the diverging lines meet the center line a little below the middle.

The lower-case letters are shown in Fig. 37. In such letters

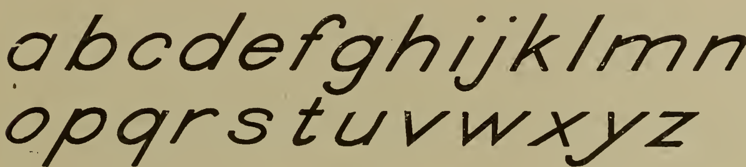


Fig. 37. Inclined Gothic Lower-Case Letters

as *m*, *n*, *r*, etc., make the corners slightly rounding. The letters *a*, *b*, *c*, *e*, *g*, *o*, *p*, *q*, should be full and rounding.

The style of the Arabic numerals is given in Fig. 36; Roman numerals are made of straight lines.

At first the copy should be followed closely and the letters drawn in pencil; the inclined guide lines may be used until the proper inclination becomes firmly fixed in mind when they should be abandoned. The horizontal lines, however, are used at all times by most draftsmen. After considerable practice has been had the letters may be constructed in ink without first using the pencil. When proficiency has been attained in the simple inclined Gothic capitals, the vertical, block and Roman alphabets should be studied.

HOW TO HOLD DRAWING INSTRUMENTS

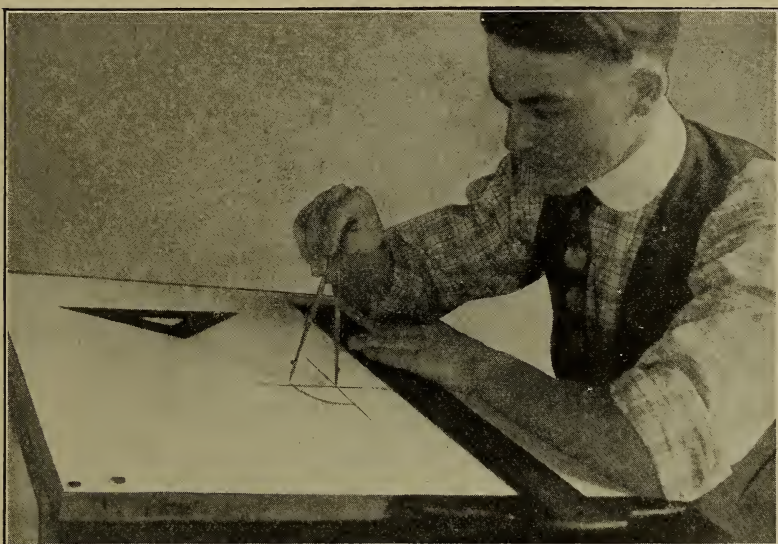
Position of Hand and Instruments. To the student who is just starting out with his drawing work, the position in which he holds his instruments and the free and easy posture of his hands are very important. Just as in playing the piano or in any other process where manual dexterity is required, this skill can only be attained by practice. The following studies should be used in connection with

Position 1. Right Line Pen against T-Square or Triangle

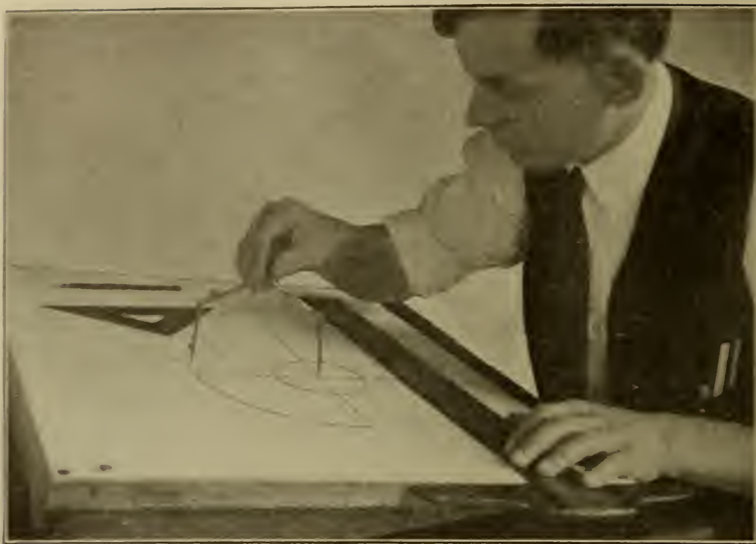
the instructions given in the forepart of this book and wherever references have been given to this section, it is expected that the student will study these plates so as to receive helpful suggestions in his work. In developing skill in Mechanical Drawing, practice is the only method of achieving results after the fundamental principles have been mastered. A very useful collection of "DON'TS" is given herewith and these will bear very close study.

Position 2. Drawing Pencil Line with T-Square and Triangle

Position 3. Inking a Line with Pen and T-Square

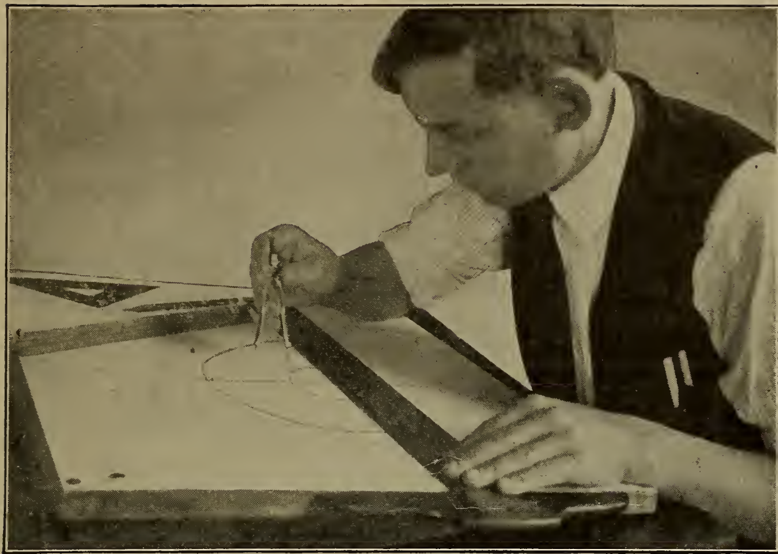


Position 4. Drawing Small Circle with the Compass



Position 5. Drawing Large Circle with Compass with Bent Legs

Position 6. Drawing Very Large Circle with Spread Compass and Lengthening Bar



Position 7. Adjusting Dividers with One Hand. Note Second and Third Fingers between Legs

"DON'TS" IN DRAFTING WORK

Don't fold a drawing.
Don't stick the dividers into the drawing board.
Don't use the dividers as picks.
Don't use the scale to rule lines.
Don't fail to clean the table, board, and instruments when beginning work.
Don't draw on the lower edge of the T-square.
Don't cut the sheets of drawing paper with the upper edge of the T-square and a knife; use the lower edge.
Don't put the end of a pencil in the mouth.
Don't oil the compass joints.
Don't put away the instruments without cleaning, especially pens.
Don't use the cheapest materials.
Don't use the T-square as a hammer.
Don't screw up the nibs of the pen too tight.
Don't use a blotter on lines that have been inked.
Don't run the pen or pencil backward over a line.
Don't fill a pen over a drawing.

PRELIMINARY LINE PROBLEMS

To lay out the paper for the plates of this work, place a sheet *A B G F*, Fig. 38, on the drawing board 2 or 3 inches from the left-hand edge, called the *working edge*. If placed near the left-hand edge, the T-square and triangles can be used with greater firmness and the horizontal lines drawn with greater accuracy. In fastening the paper on the board, always true it up with the T-square according to the long edge of the sheet and use at least 4 thumb tacks —one at each corner. If the paper has a tendency to curl, 6 or 8

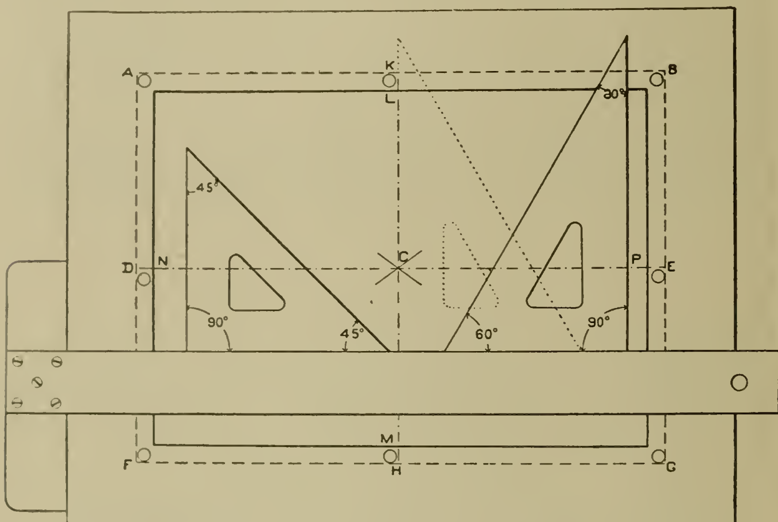


Fig. 38. Standard Lay-Out for Plates

tacks may be used placing them as shown in Fig. 38; many draftsmen prefer one-ounce tacks as they offer less obstruction to the T-square and triangles.

To find the center of the sheet place the T-square so that its upper edge coincides with the diagonal corners *A* and *G* and with the corners *F* and *B*, and draw short pencil lines intersecting at *C*. Now with the T-square draw through the point *C* the dot and dash line *D E*, and with the T-square and one of the triangles—shown dotted in Fig. 38—draw the dot and dash line *H C K*. It will probably be necessary to draw *CK* first and then by means of the T-square or triangle, produce (extend) *CK* to *H*. In this work always move

the pencil from left to right or from the bottom upward; except in certain cases.

After the center lines are drawn measure off 5 inches above and below the point C on the line $H\ C\ K$. These points L and M may be indicated by a light pencil mark or by a *slight* puncture by means of one of the points of the dividers. Now place the T-square against the left-hand edge of the board and draw horizontal pencil lines through L and M.

Measure off 7 inches to the left and right of C on the center line $D\ C\ E$ and draw pencil lines through these points N and P, perpendicular to DE. These lines form a rectangle 10 inches by 14 inches, in which all the exercises and figures are to be drawn. The lettering of the student's name and address, date, and plate number are to be placed *outside* of this rectangle in the ½-inch margin. In all cases lay out the plates in this manner and keep the center lines $D\ E$ and $K\ H$ as a basis for the various figures. Ink in the border line with a heavy line when the drawing is finished.

Penciling. In laying out the first few plates of this course the work is to be done in pencil and then inked in; later the subject of tracing the pencil drawings on tracing cloth and the process of making blue prints from these tracings will be taken up. Every beginner should practice with his instruments until he understands them thoroughly and can use them with accuracy and skill. To aid the beginner in this work, the first three plates of this course are practice plates; they do not involve any problems and none of the work is difficult. The student is strongly advised to draw these plates two or three times before making the one to be sent to us for correction. Diligent practice is necessary at first; especially on *Plate I* as it involves an exercise in lettering.

Inking. To ink a drawing well requires great care and some experience. The student should not attempt to ink in his work until he can make a clear-cut, straight line with ease. It is well to practice inking in straight pencil lines, rectangles, and triangles in order to improve the work on lines, corners, and intersections. These latter should be very definite, each line stopping at exactly the right point.

Before starting to ink in, adjust the pen by means of the thumb screw until a good clear line of the desired width is obtained, making frequent test lines, on a piece of material similar to that which is to

be used. Keep the pressure of the pen on the paper uniformly light, remembering that different weights of lines are not obtained by pressure as with the ordinary writing pen but only by adjusting the nibs of the pen. If the lines are ragged the pen should be put in order, according to the instructions already given. Sometimes when the ink does not flow regularly, moisten the end of the finger and touch the point of the pen. Care should be taken not to put too much ink in the pen, but on the other hand there must be enough to draw the next line as it is difficult to continue a line after re-filling the pen. The only way to draw fine lines well is to frequently clean and re-fill the pen. If the amount of ink in the pen is small it is quite likely to thicken in the point and cause clogging. When this occurs, draw a small strip of paper between the nibs to clean out the clogged ink.

When drawing, the pen should be held with the thumb screw out and should be inclined slightly in the direction in which it is moved. Be careful, however, not to incline it too much, as the best of pens when incorrectly held will produce poor lines. It is therefore advisable at the start to acquire the correct method of holding the pen. Do not press the sides of the pen point too heavily against the ruling edge as this will vary the width of the line; after a little practice the pen can be lightly and firmly brought in contact with the paper and ruling edge at the same time. The pen should be drawn from left to right, the hand being steadied by sliding it on the end of the little finger.

Always try to get into the easiest position when inking a line, even if it becomes necessary to walk around the drawing. The average draftsman prefers the standing position while inking as he can usually obtain much better results. Keep the ruling edge between the line and the body so that the pen will be drawn against the ruling edge, for if this is not done, the pen is liable to be pulled off at an angle, making a crooked line. Be careful after inking a line to draw the ruling edge toward the body away from the line in order to avoid blotting. Where lines meet at a point, always ink towards the point, being sure to allow one line to dry before inking another. Always ink in the top and left-hand lines first, gradually working down to the right, thus saving time that otherwise would be lost in waiting for the lines to dry. When the pen is set at the proper width, draw all the lines of that width before making a change. Never push

the pen backward over a line. If a good line is not drawn the first time, it is better to go over it again in the same direction, taking great care not to widen the original line.

Ink dries very quickly and should not be left in the pen on account of its corrosive effects. The celluloid triangles should be washed frequently in water and all ink spots removed.

In using the compass, bend both legs so that each will be perpendicular to the paper or cloth when the arc or circle is drawn. When the pen attachment is used special care must be exercised on this point for in no other way can the nibs of the pen be made to bear evenly on the surface. In drawing arcs, hold the cylindrical handle at the top of the compass loosely between the thumb and the forefinger and let it roll between the two during rotation; allow the compass to lean slightly in the direction of rotation, pressing down the pen point slightly but not the needle point. Be sure to fix the needle point firmly in its proper place on the paper before touching the pen to the paper, as otherwise a slip is likely to occur. In setting the needle down on any particular center, guide it with a finger of the left hand. Avoid making a noticeable hole in the paper.

Ink in the circumference of a circle with one continuous motion, giving an even pressure to the pen throughout the operation and stopping it sharply at the end of one revolution. Since straight lines can be more easily drawn tangent to curves than the reverse, it is always advisable to ink in all arcs or circles first. When a number of circles are to be drawn from one center, the smaller should be inked first while the center is in the best possible condition.

PLATE I

Penciling. To draw *Plate I,** take a sheet of drawing paper at least 11 inches by 15 inches and fasten it to the drawing board as already explained. Find the center of the sheet and draw fine pencil lines to represent the lines *DE* and *HK* of Fig. 38. Also draw the border lines *L*, *M*, *N*, and *P*.

Now measure $\frac{3}{8}$ inch above and below the horizontal center line and, with the T-square, draw lines through these points. These lines will form the lower lines *DC* of Fig. 1 and Fig. 2 and the top lines *AB* of Fig. 3 and Fig. 4. Measure $\frac{3}{8}$ inch to the right and left

*Note Instructions, pages 22 to 25, inclusive.

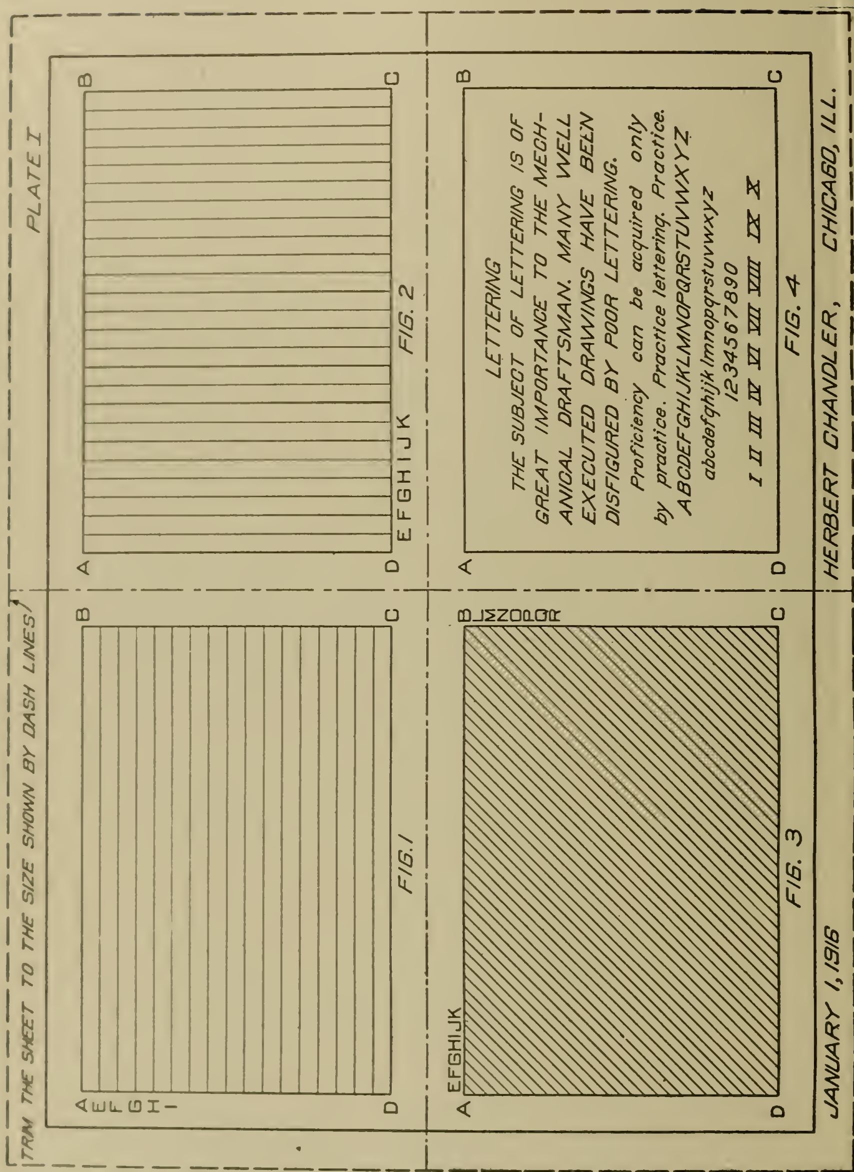


PLATE I
TRIM THE SHEET TO THE SIZE SHOWN BY DASH LINES
A B C D E F G H I J K
FIG. 1
FIG. 2
LETTERING
THE SUBJECT OF LETTERING IS OF
GREAT IMPORTANCE TO THE MECH-
ANICAL DRAFTSMAN. MANY WELL
EXECUTED DRAWINGS HAVE BEEN
DISFIGURED BY POOR LETTERING.
Proficiency can be acquired only
by practice. Practice lettering. Practice.
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
I II III IV VI VII VIII IX X
FIG. 3
FIG. 4
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 1, 1916

of the vertical center line; and through these points, draw lines parallel to the center line. These lines should be drawn by placing the triangle on the T-square as shown in Fig. 38. The lines thus drawn, form the sides *B C* of Fig. 1 and Fig. 3 and the sides *A D* of Fig. 2 and Fig.4. Next draw, with the T-square, the line *A B A B* $4\frac{5}{8}$ inches above the horizontal center line, and the line *D C D C* $4\frac{5}{8}$ inches below the horizontal center line. The rectangles of the four figures may now be completed by drawing vertical lines $6\frac{5}{8}$ inches on each side of the vertical center line; these rectangles are each $6\frac{1}{4}$ inches long and $4\frac{1}{4}$ inches wide.

Fig. 1. *Exercise with Line Pen and T-square.* Divide the line *A D* into divisions each $\frac{1}{4}$ inch long, making a fine pencil point or *slight* puncture at each division such as *E, F, G, H, I,* etc. Now place the T-square with its head at the left-hand edge of the drawing board and through these points draw light pencil lines extending to the line *B C.* In drawing these lines the pencil point must pass *exactly* through the division marks so that the lines will be the same distance apart. Start each line in the line *A D* and do not fall short of the line *B C* or run over it. Accuracy and neatness in penciling insure an accurate drawing. Some beginners think that they can correct inaccuracies while inking; but experience soon teaches them that they cannot do so.

Fig. 2. *Exercise with Line Pen, T-square and Triangle.* Divide the lower line *D C* of the rectangle into divisions each $\frac{1}{4}$ inch long and mark the points *E, F, G, H, I, J, K,* etc., as in Fig. 1. Place the T-square about as shown in Fig. 38, and either triangle in position with its 90-degree angle at the left. Now draw fine pencil lines from the line *D C* to the line *A B* passing through the points *E, F, G, H, I, J, K,* etc., keeping the T-square rigid and sliding the triangle toward the right.

Fig. 3. *Exercise with Line Pen T-square and 45-degree Triangle.* Lay off the distances *A E, B L,* etc., each $\frac{1}{4}$ inch long on *A B* and *B C,* respectively. Place the T-square so that the upper edge will be below the line *D C,* and, with the 45-degree triangle, draw the diagonal lines through the points laid off. In drawing these lines move the pencil away from the body, *i. e.,* from *A D* to *A B* and from *D C* to *B C.*

Fig. 4. *Exercise in Free-Hand Lettering.* Draw the center line *E F,* Fig. 39, and light pencil lines *Y Z* and *T X,* $\frac{3}{8}$ inch from the

border lines. With the T-square, draw the line G, $\frac{1}{4}$ inch from the top line and the line H, $\frac{5}{32}$ inch below G. The word "*LETTERING*" is to be placed between these two lines. Draw the line I, $\frac{3}{16}$ inch below H, and space the lines included between I and K, $\frac{5}{32}$ inch apart.

The next style of letters to be discussed is lower-case letters. Draw the line L $\frac{3}{16}$ inch below K and to limit the height of the small letters draw a light line $\frac{1}{8}$ inch above L.

Make the space between L and M, $\frac{5}{32}$ inch and draw M and N in the same manner as K and L. Now draw O, $\frac{3}{16}$ inch below N,

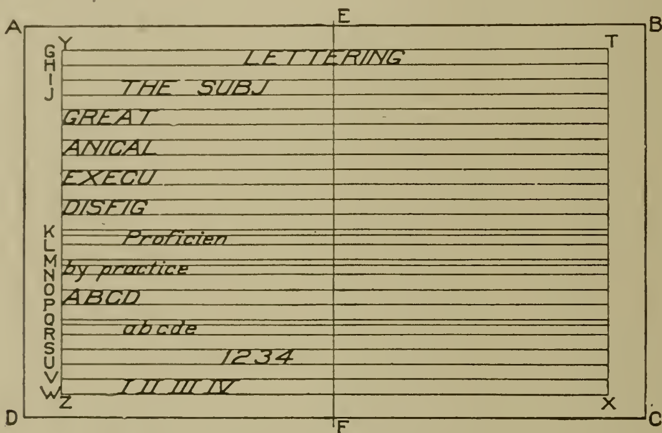


Fig. 39. Sample Lettering Plate—Fig. 4., Plate I

P, $\frac{5}{32}$ inch below O, and Q, $\frac{5}{32}$ inch below P. Space Q and R as K and L, and draw S, U, V, and W, $\frac{5}{32}$ inch apart.

The center line is a great aid in centering the word "*LETTERING*," the alphabets, numerals, etc. Indent the words "*THE*" and "*Proficiency*" about $\frac{3}{8}$ inch, as they are the first words of paragraphs. To draw the guide lines, mark off distances of $\frac{1}{4}$ inch on any line such as J and with the 60-degree triangle draw light pencil lines cutting the parallel lines. Sketch the letters in pencil making the width of the ordinary letters such as E, F, H, N, R, etc., about $\frac{3}{4}$ their height. Letters like A, M, and W, are wider. The space between the letters depends upon the draftsman's taste, but the beginner should remember that letters next to an A or an L should be placed nearer to them than to letters whose sides are parallel: for

instance there should be more space between an N and E than between an E and H. Similarly a greater space should be left on either side of an I. On account of the space above the lower line of the L, a letter following an L should be close to it. If a T follows a T or an L follows an L place them near together. In all lettering place the letters so that the general effect is pleasing. After the four figures are completed, pencil in the lettering for name, address, and date. With the T-square draw a pencil line $\frac{5}{32}$ inch above the top border line at the right-hand end, and about 3 inches long. At a distance of $\frac{5}{32}$ inch above this line draw another line of about the same length. These are the guide lines for the word *Plate I*. Pencil the letters free-hand using the 60-degree guide lines if desired.

Draw in a similar manner the guide lines of the date, name, and address in the lower margin, the date of completing the drawing placed under Fig. 3, and the name and address at the right, under Fig. 4. The street address is unnecessary. It is a good plan to draw lines $\frac{5}{32}$ inch apart on a separate sheet of paper and pencil the letters in order to know just how much space each word will require. The insertion of the words "Fig. 1," "Fig. 2," etc., is optional with the student, but it is advised that he do this extra lettering for the practice as well as for convenience in reference. First draw with the T-square two parallel lines $\frac{5}{32}$ inch apart under each exercise, the lower line being $\frac{1}{16}$ inch above the horizontal center line or above the lower border line.

Inking. After all of the penciling of *Plate I* has been completed the exercises should be inked. Before doing this, however, see that the pen is in proper condition, and after filling try it on a separate piece of paper in order that the proper width of line may be drawn. In the first work where no shading is done, use a firm, distinct line. The beginner should avoid the extremes; a very light line makes the drawing appear weak and indistinct, while a very heavy line detracts from its artistic appearance.

Ink in all the horizontal lines of Fig. 1 first, moving the T-square from A to D, and take great care to start and stop the lines exactly on the vertical boundary lines. It is necessary to use both triangle and T-square for inking $A\ D$ and $B\ C$. In inking Fig. 2 and Fig. 3, follow the same directions as for penciling, inking in the vertical and oblique lines first and then the border lines. Ink the border lines

of Fig. 4 first and then the border lines of the plate, making the latter very heavy and the intersections accurate. The lettering in Fig. 4 should be done free-hand, using a steel pen not finer than a Gillott 404. Now ink in the four figure numbers, plate number, date, and name, also free-hand, and then erase the pencil lines. **In the finished drawing there should be no center lines, construction lines, or letters other than those in the name, date, etc.**

Cut the sheet 11″ × 15″, the dash line outside the border line of *Plate I* indicating the edge.

PLATE II

Penciling. The horizontal and vertical center lines and the border lines for *Plate II* are laid out in the same manner as were those of *Plate I*. To draw the squares for the six figures, proceed as follows:

Measure off two inches on either side of the vertical center line and draw light pencil lines through these points parallel to the vertical center line. These lines will form the sides *A D* and *B C* of Fig. 2 and Fig. 5. Parallel to these lines and at a distance of $\frac{1}{2}$ inch draw similar lines to form the sides *B C* of Fig. 1 and Fig. 4 and *A D* of Fig. 3 and Fig. 6. The vertical sides *A D* of Fig. 1 and Fig. 4 and *B C* of Fig. 3 and Fig. 6 are formed by drawing lines perpendicular to the horizontal center line at a distance of $6\frac{1}{2}$ inches from the center.

Complete the figures by laying off lines $\frac{1}{2}$ inch and $4\frac{1}{2}$ inches above and below the horizontal center line respectively, thus forming six 4-inch squares.

In drawing Fig. 1, divide *A D* and *A B* into 4 equal parts, then draw horizontal lines through *E*, *F*, and *G* and vertical lines through *L*, *M*, and *N*. Draw lines from *A* and *B* to the intersection *O* of lines *E* and *M*, and from *A* and *D* to the intersection *P* of lines *F* and *L*. Similarly draw *D J*, *J C*, *C I*, and *I B*. Also connect the points *O*, *P*, *J*, and *I*, thus forming a square. The four diamond-shaped areas are formed by drawing lines from the middle points of *A D*, *A B*, *B C*, and *D C* to the middle points of lines *A P*, *A O*, *O B*, *I B*, etc., as shown in Fig. 1.

Fig. 2 is an exercise of straight lines. Divide *A D* and *A B* into four equal parts and draw horizontal and vertical lines as in Fig. 1. Now divide these dimensions, *A L*, *M N*, etc., and *E F*,

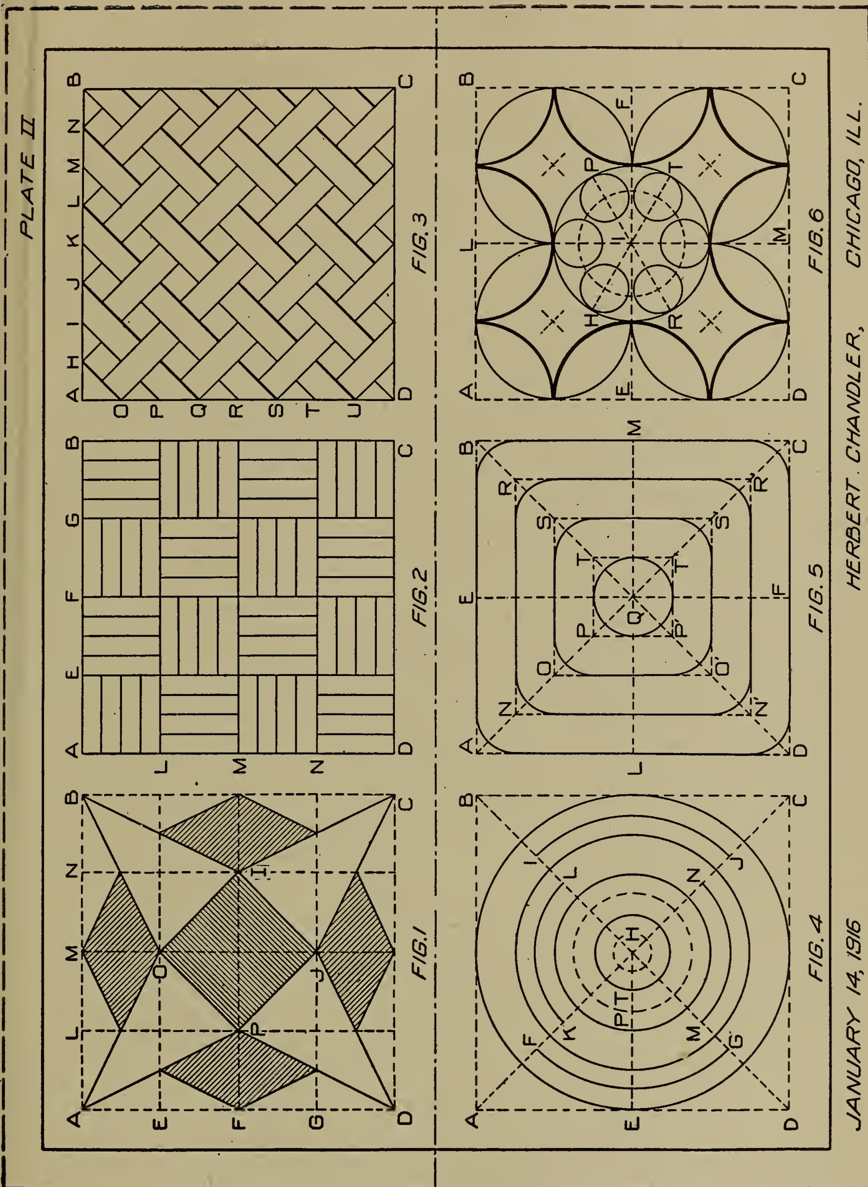


PLATE II
FIG.1
FIG.2
FIG.3
FIG.4
FIG.5
FIG.6
HERBERT. CHANDLER, CHICAGO, ILL.
JANUARY 14, 1916

G B, etc., into four equal parts—each $\frac{1}{4}$ inch—and draw light pencil lines with the T-square and triangle as shown.

In Fig. 3, divide *A D* and *A B* into eight equal parts, and through the points *O*, *P*, *Q*, *H*, *I*, *J*, etc., draw horizontal and vertical lines. Now draw lines connecting *O* and *H*, *P* and *I*, *Q* and *J*, etc. As these lines form an angle of 45 degrees with the horizontal, a 45-degree triangle may be used. Similarly from each one of the given points on *A B* and *A D*, draw lines at an angle of 45 degrees to *B C* and *D C* respectively.

Fig. 4 is drawn with the compasses. Draw the diagonals *A C* and *D B*, and with the T-square draw the line *E H*. Now mark off on *E H* distances of $\frac{1}{4}$ inch, and with *H* as a center describe, by means of the compasses, circles having radii respectively 2 inches, $1\frac{1}{2}$ inches, 1 inch, $\frac{3}{4}$ inch, $\frac{1}{2}$ inch, and $\frac{1}{4}$ inch. Similarly with *H* as a center and a radius of $1\frac{3}{4}$ inches and $1\frac{1}{4}$ inches respectively draw the arcs *F G* and *I J* and *K L* and *M N*, being careful to end the arcs in the diagonals.

Fig. 5 is an exercise with the line pen and compasses. Draw the diagonals *A C* and *D B*, the horizontal line *L M* and the vertical line *E F* passing through the center *Q*. Mark off distances of $\frac{1}{2}$ inch on *L M* and *E F* and complete the squares *N R R′ N′*, etc. With the bow pencil adjusted so that the distance between the pencil point and the needle point is $\frac{1}{2}$ inch, draw arcs having centers at the corners of the inner squares. The arc whose center is *N* will be tangent to the lines *A L* and *A E* and the arc whose center is *O* will be tangent to *N N′* and *N R*. Since the smallest square has 1 inch sides, the $\frac{1}{2}$-inch arcs drawn with *Q* as a center will form a circle.

In Fig. 6, draw the center lines *E F* and *L M*, and find the centers of the four squares thus formed. Through the center *I* draw the construction lines *H I T* and *R I P* forming angles of 30 degrees with *EF*. Now adjust the compasses to draw circles having a radius of one inch, and with *I* as a center, draw the circle *H P T R*. With the same radius draw the arcs with centers at *A*, *B*, *C*, and *D*, and also draw the semicircles with centers at *L*, *F*, *M*, and *E*. Now draw the arcs as shown having centers at the centers of the four squares. To locate the centers of the six small circles within the circle *H P T R*, draw a circle with a radius of $\frac{11}{16}$ inch and having the center in *I*. The small circles each have a radius of $\frac{5}{16}$ inch.

Inking. In *Plate II* ink in only the lines shown *full* in the specimen plate. First ink the star and then the square and diamonds. As this is an exercise for practice, the cross-hatching should be done *without* measuring the distance between the lines and without the aid of any cross-hatching device. The lines should be about $\frac{1}{16}$ inch apart. After inking in the plate all construction lines should be erased.

In inking Fig. 2 first ink the principal horizontal and vertical lines and then very carefully ink in the short lines. Make these lines all of the same width.

Fig. 3 is drawn entirely with the 45-degree triangle. In inking the oblique lines make $P\ I$, $R\ K$, $T\ M$, etc., of the usual width, while the alternate lines $O\ H$, $Q\ J$, $S\ L$, etc., should be somewhat heavier. All of the lines which slope in the opposite direction are light. Now ink in the border lines and erase all other horizontal and vertical lines.

In inking Fig. 4 use only the compasses, adjusting the legs so that the pen will always be perpendicular to the paper. In inking the arcs, see that the pen stops *exactly* at the diagonals. The inner circle and the next but one should be dotted as shown in the specimen plate. After inking the circles and arcs erase the construction lines that are without the outer circles, leaving in *pencil* the diagonals inside the circles.

In Fig. 5 *draw all arcs first* and then the straight lines meeting these arcs, as it is much easier to make a straight line meet an arc or tangent to it, than the reverse. Leave all construction lines in pencil. This exercise is difficult, and as in all mechanical and machine drawing, arcs and tangents are frequently used, the beginner is advised to draw this exercise several times.

Fig. 6 is an exercise with compasses. If the laying out has been accurately done in pencil, the inked arcs will be tangent to each other and the finished exercise will have a good appearance. If, however, the distances were not accurately measured and the lines carefully drawn, the inked arcs will not be tangent. The arcs whose centers are L, F, M, and E, and A, B, C, and D should be heavier than the rest. The small circles may be drawn with the bow pen. After inking the arcs all construction lines should be erased.

Finally ink in the figure numbers, the border lines of the plate, name, address, and plate number as in *Plate I.*

PLATE III

Penciling. *Plate III* should be laid out in the same manner as *Plate II,* that is, for size and border lines. In laying out the sixteen rectangles, however, the space between the center lines and rectangles must in every case be made $\frac{1}{2}$ inch. Each rectangle is to be filled in with what is called *section lining,* illustrating the material of which the object is composed, and, therefore, differing accordingly. The conventions here shown are standard, and some of them will be used by the student in later work in Machine Drawing. Familiarity with them is of value to any draftsman. In drawing section lines of this character, the closeness of the lines should be governed by the area being sectioned. For large areas use a rather wide spacing; for small areas use a narrow spacing. In showing a section of any machine, the different parts are distinguished by altering the slope of the section lines, whether of the same material or not.

Draw the sixteen figures in full and then draw the border lines of the plate. Make the lettering conform to that in *Plate I* and *Plate II.*

Inking. After all the penciling of *Plate III* has been completed, the exercise should be inked, including the titles.

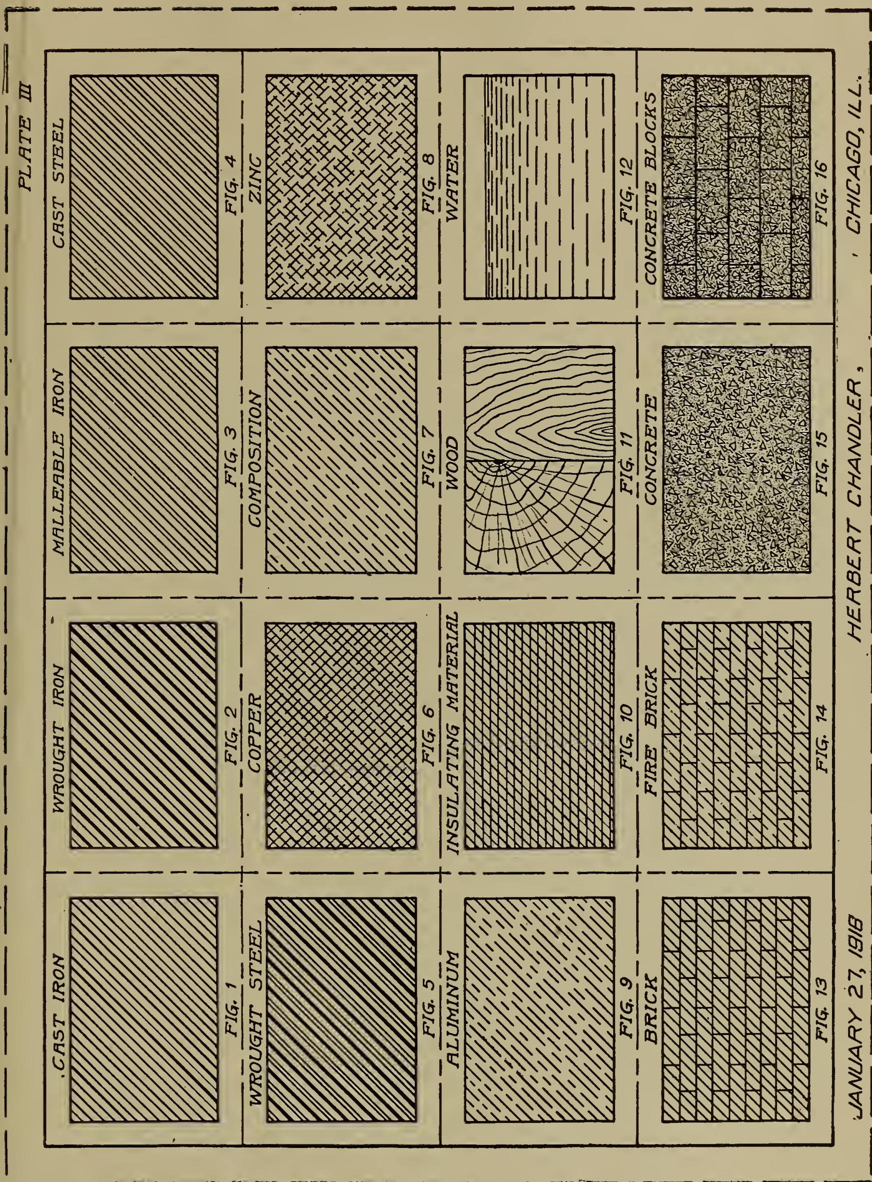


PLATE III
CAST IRON
FIG. 1
WROUGHT IRON
FIG. 2
MALLEABLE IRON
FIG. 3
CAST STEEL
FIG. 4
WROUGHT STEEL
FIG. 5
COPPER
FIG. 6
COMPOSITION
FIG. 7
ZINC
FIG. 8
ALUMINUM
FIG. 9
INSULATING MATERIAL
FIG. 10
WOOD
FIG. 11
WATER
FIG. 12
BRICK
FIG. 13
FIRE BRICK
FIG. 14
CONCRETE
FIG. 15
CONCRETE BLOCKS
FIG. 16
JANUARY 27, 1918
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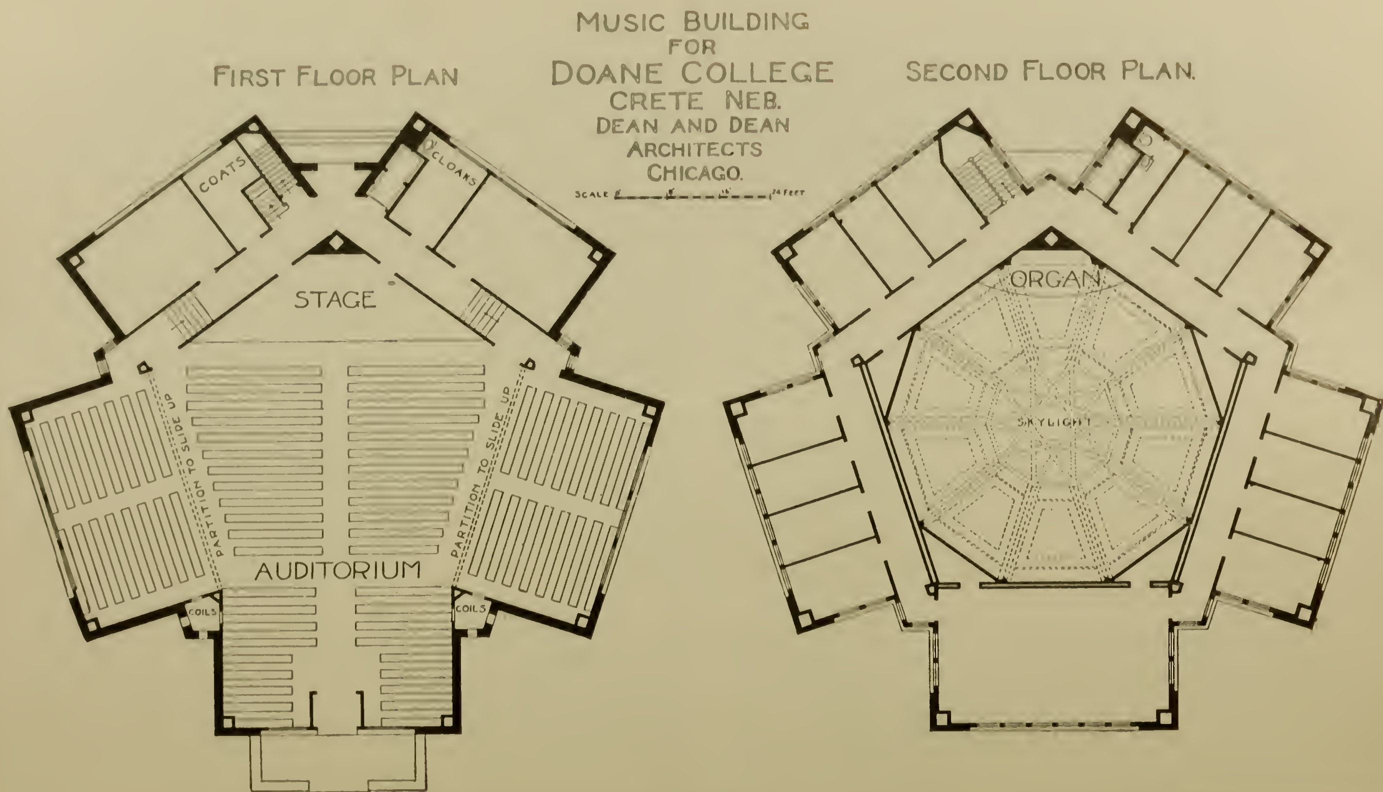

FIRST AND SECOND FLOOR PLANS OF MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA

Dean and Dean, Architects, Chicago, Illinois

MECHANICAL DRAWING

PART II

In Part I the instructions and the problems worked out have been designed to teach the student the elementary operations of Mechanical Drawing, giving him a knowledge of the instruments, an ability to draw a straight and true line, and to make up simple figures. A fair degree of drawing ability is now assumed and we can pass on to more complicated problems. Wherever we turn for subjects, however, we find a knowledge of geometrical figures and their properties is absolutely essential to a clear understanding of the problems chosen and we will therefore turn to a discussion of these geometrical figures and the problems which involve them.

GEOMETRICAL DEFINITIONS

A *point* is used for marking position; it has neither length, breadth, nor thickness.

LINES

A *line* has length only; it is produced by the motion of a point.

A *straight line* or *right line* is one that has the same direction throughout. It is the shortest distance between two points.

A *curved line* is one that is constantly changing in direction. It is sometimes called a curve.

A *broken line* is one made up of several straight lines.

Parallel lines are lines which lie in the same plane and are equally distant from each other at all points.

A *horizontal line* is one having the direction of a line drawn upon the surface of water that is at rest. It is a line parallel to the horizon.

A *vertical line* is one that lies in the direction of a thread suspended from its upper end and having a weight at the lower end. It is a line that is perpendicular to a horizontal plane.

An *oblique line* is one that is neither vertical nor horizontal.

In Mechanical Drawing, lines drawn along the edge of the T-square, when the head of the T-square is resting against the left-hand edge of the board, are called *horizontal* lines. Those drawn at right angles or perpendicular to the edge of the T-square are called *vertical* lines.

If two lines cut each other, they are called *intersecting lines*, and the point at which they cross is called the *point of intersection.*

ANGLES

An *angle* is the measure of the difference in direction of two lines. The lines are called *sides,* and the point of meeting, the

Fig. 40. Right Angle

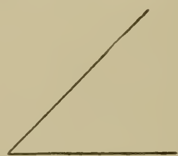

Fig. 41. Acute Angle

Fig. 42. Obtuse Angle

vertex. The size of an angle is independent of the length of the lines.

If one straight line meets another (extended if necessary), Fig. 40, so that the two angles thus formed are equal, the lines are said to be *perpendicular* to each other and the angles formed are called *right angles.*

An *acute angle* is less than a right angle, Fig. 41.

An *obtuse angle* is greater than a right angle, Fig. 42.

SURFACES

A *surface* is produced by the motion of a line; it has two dimensions—length and breadth.

A *plane figure* is a plane bounded on all sides by lines; the space included within these lines (if they are straight lines) is called a *polygon* or a *rectilinear figure.*

POLYGONS

A *polygon* is a plane figure bounded by straight lines. The boundary lines are called the *sides* and the sum of the sides is called the *perimeter.*

Polygons are classified according to the number of sides.

A *triangle* is a polygon of *three* sides.

A *quadrilateral* is a polygon of *four* sides.

A *pentagon* is a polygon of *five* sides, Fig. 43.

A *hexagon* is a polygon of *six* sides, Fig. 44.

A *heptagon* is a polygon of *seven* sides.

An *octagon* is a polygon of *eight* sides, Fig. 45.

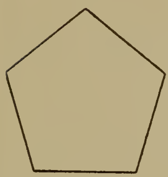

Fig. 43. Pentagon

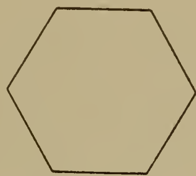

Fig. 44. Hexagon

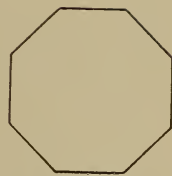

Fig. 45. Octagon

A *decagon* is a polygon of *ten* sides.

A *dodècagon* is a polygon of *twelve* sides.

An *equilateral* polygon is one all of whose sides are equal.

An *equiangular* polygon is one all of whose angles are equal.

A *regular* polygon is one all of whose angles and all of whose sides are equal.

Triangles. A triangle is a polygon enclosed by three straight lines called *sides*. The *angles* of a triangle are the angles formed by the sides.

A *right-angled* triangle, often called a *right* triangle, Fig. 46, is one that has a right angle. The longest side (the one opposite

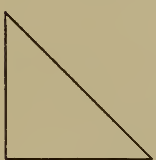

Fig. 46. Right-Angled Triangle

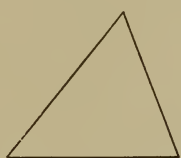

Fig. 47. Acute Angled Triangle

Fig. 48. Obtuse-Angled Triangle

the right angle) is called the *hypotenuse,* and the other sides are sometimes called *legs*.

An *acute-angled* triangle is one that has all of its angles acute, Fig. 47.

An *obtuse-angled* triangle is one that has an obtuse angle, Fig. 48.

An *equilateral* triangle is one having all of its sides equal, Fig. 49.

An *equiangular* triangle is one having all of its angles equal.

An *isosceles* triangle, Fig. 50, is one, two of whose sides are equal.

A *scalene* triangle, Fig. 51, is one, no two of whose sides are equal.

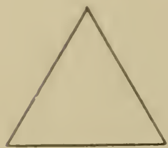

Fig. 49. Equilateral Triangle

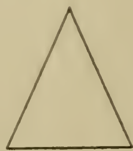

Fig. 50. Isosceles Triangle

Fig. 51. Scalene Triangle

The base of a triangle is the lowest side; it is the side upon which the triangle is supposed to stand. Any side may, however, be taken as the base. In an isosceles triangle, the side which is not one of the equal sides is usually considered as the base.

The *altitude* of a triangle is the perpendicular drawn from the vertex to the base.

Quadrilaterals. A quadrilateral is a polygon bounded by four straight lines, as Fig. 52.

The *diagonal* of a quadrilateral is a straight line joining two opposite vertices.

Trapezium. A trapezium is a quadrilateral, no two of whose sides are parallel.

Trapezoid. A trapezoid is a quadrilateral having two sides

Fig. 52. Quadrilateral

Fig. 53. Trapezoid

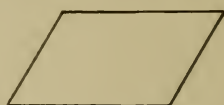

Fig. 54. Parallelogram

parallel, Fig. 53. The parallel sides are called the *bases* and the perpendicular distance between the bases is called the *altitude.*

Parallelogram. A parallelogram is a quadrilateral whose opposite sides are parallel, Fig. 54.

There are four kinds of parallelograms: rectangle, square, rhombus, and rhomboid.

The *rectangle,* Fig. 55, is a parallelogram whose angles are right angles.

The *square,* Fig. 56, is a parallelogram all of whose sides are equal and whose angles are right angles.

The *rhombus*, Fig. 57, is a parallelogram whose sides are equal but whose angles are not right angles.

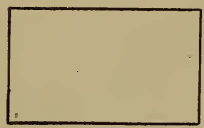

Fig. 55. Rectangle

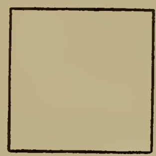

Fig. 56. Square

Fig. 57. Rhombus

The *rhomboid* is a parallelogram whose adjacent sides are unequal, and whose angles are not right angles.

CIRCLES

A *circle* is a plane figure bounded by a curved line called the *circumference*, every point of which is equally distant from a point within called the *center*, Fig. 58.

A *diameter* of a circle is a straight line drawn through the center, terminating at both ends in the circumference, Fig. 59.

A *radius* of a circle is a straight line joining the center with the circumference. All radii of the same circle are equal and their length is always one-half that of the diameter.

Fig. 58. Circle

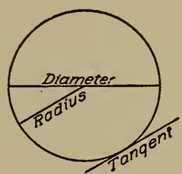

Fig. 59. Diameter, Radius, Tangent

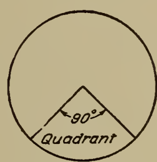

Fig. 60. Quadrant

An *arc* is any part of the circumference of a circle. An arc equal to one-half the circumference is called a *semi-circumference*, and an arc equal to one-quarter of the circumference is called a *quadrant*, Fig. 60. A quadrant may mean the arc or angle.

A *chord*, Fig. 61, is a straight line which joins the extremities of an arc but does not pass through the center of the circle.

A *secant* is a straight line which intersects the circumference in two points, Fig. 61.

A *segment* of a circle, Fig. 62, is the area included between an arc and a chord.

A *sector* is the area included between an arc and two radii drawn to the extremities of the arc, Fig. 62.

A *tangent* is a straight line which touches the circumference at only one point, called the *point of tangency or contact,* Fig. 59.

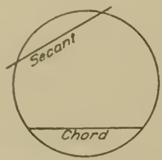

Fig. 61. Chord and Secant

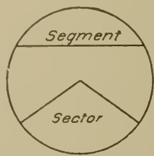

Fig. 62. Segment and Sector

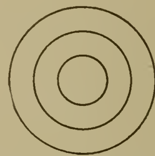

Fig. 63. Concentric Circles

Concentric circles are circles having the same center, Fig. 63.

An *inscribed angle* is an angle whose vertex lies in the circumference and whose sides are chords. It is measured by one-half the intercepted arc, Fig. 64.

A *central angle* is an angle whose vertex is at the center of the circle and whose sides are radii, Fig. 65.

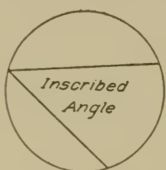

Fig. 64. Inscribed Angle

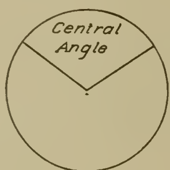

Fig. 65. Central Angle

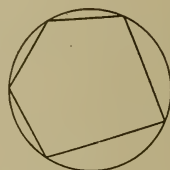

Fig. 66. Inscribed Polygon

An *inscribed polygon* is one whose vertices lie in the circumference and whose sides are chords, Fig. 66.

MEASUREMENT OF ANGLES

To measure an angle, take any convenient radius and describe an arc with the center at the vertex of the angle. The portion of the arc included between the sides of the angle is the *measure of the angle.* If the arc has a constant radius, the greater the divergence of the sides, the longer will be the arc. If there are several arcs drawn with the same center, the intercepted arcs will have different lengths but they will all be the *same fraction* of the entire circumference.

In order that the size of an angle or arc may be stated without saying that it is a certain fraction of a circumference, the circumference is divided into 360 equal parts called *degrees,* Fig. 67. Thus, it may be said that a certain angle contains 45 degrees, *i.e.,* it is $\frac{45}{360}=\frac{1}{8}$ of a circumference. In order to obtain accurate measurements each degree is divided into 60 equal parts called *minutes* and each minute into 60 equal parts called *seconds.*

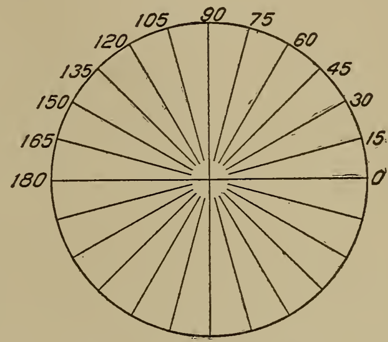

Fig. 67. Angular Measurement

SOLIDS

A *solid* has three dimensions—length, breadth, and thickness. The most common forms of solids are *polyhedrons, cylinders, cones,* and *spheres.*

POLYHEDRONS

A *polyhedron* is a solid bounded by planes. The bounding planes are called *faces* and their intersections are called *edges.* The intersections of the edges are called *vertices.*

A polyhedron having four faces is called a *tetrahedron;* one having six faces, a *hexahedron;* one having eight faces, and *octahedron,* Fig. 68; one having twelve faces, a *dodecahedron,* etc.

Prisms. A prism is a polyhedron having two opposite faces, called *bases,* which are equal and parallel, and other faces, called

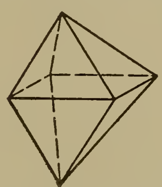

Fig. 68. Octahedron

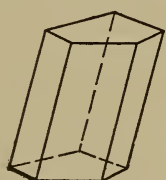

Fig. 69. Prism

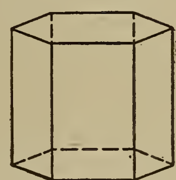

Fig. 70. Right Prism

lateral faces, which are parallelograms, Fig. 69. The *altitude* of a prism is the perpendicular distance between the bases. The area of the lateral faces is called the *lateral area.*

Prisms are called *triangular, rectangular, hexagonal,* etc., according to the shape of the bases. Further classifications are as follows:

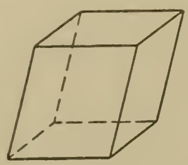

Fig. 71. Parallelopiped

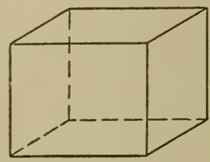

Fig. 72. Rectangular Parallelopiped

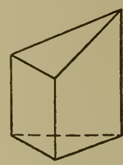

Fig. 73. Truncated Prism

A *right* prism is one whose lateral faces are perpendicular to the bases, Fig. 70.

A *regular* prism is a right prism having regular polygons for bases.

Parallelopiped. A parallelopiped is a prism whose bases are parallelograms. Fig. 71. If all the edges are perpendicular to the bases, it is called a *right parallelopiped.*

A *rectangular parallelopiped* is a right parallelopiped whose bases and lateral faces are rectangles, Fig. 72.

A *cube* is a rectangular parallelopiped all of whose faces are squares.

A *truncated prism* is the portion of a prism included between the base and a plane not parallel to the base, Fig. 73.

Pyramids. A pyramid is a polyhedron whose base is a polygon and whose lateral faces are triangles having a common vertex called the *vertex* of the pyramid.

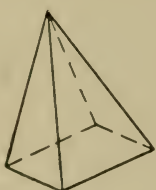

Fig. 74. Pyramid

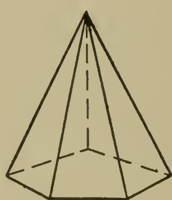

Fig. 75. Regular Pyramid

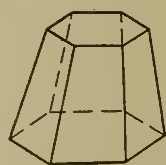

Fig. 76. Frustum of Pyramid

The *altitude* of the pyramid is the perpendicular distance from the vertex to the base.

Pyramids are named according to the kind of polygon forming the base, viz, *triangular, quadriangular,* Fig. 74. *pentagonal,* Fig. 75, *hexagonal.*

A *regular pyramid* is one whose base is a regular polygon and whose vertex lies in a perpendicular erected at the center of the base, Fig. 75.

A *truncated* pyramid is the portion of a pyramid included between the base and a plane not parallel to the base.

A *frustum* of a pyramid is the solid included between the base and a plane parallel to the base, Fig. 76; its *altitude* is the perpendicular distance between the bases.

CYLINDERS

A *cylinder* is a solid having as bases two equal parallel surfaces bounded by curved lines, and as its lateral face the continuous

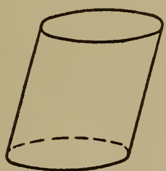

Fig. 77. Cylinder

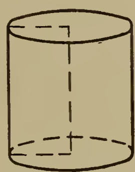

Fig. 78. Right Cylinder

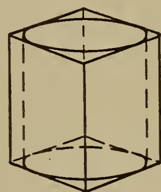

Fig. 79. Inscribed Cylinder

surface generated by a straight line connecting the bases and moving along their circumferences. The bases are usually circles and such a cylinder is called a *circular cylinder*, Fig. 77.

A *right cylinder*, Fig. 78, is one whose side is perpendicular to the bases.

The *altitude* of a cylinder is the perpendicular distance between the bases.

A prism whose base is a regular polygon may be inscribed in or circumscribed about a circular cylinder, Fig. 79.

CONES

A *cone* is a solid bounded by a conical surface and a plane which cuts the conical surface. It may be considered as a pyramid with an infinite number of sides, Fig. 80.

The conical surface is called the *lateral area* and it tapers to a point called the *vertex;* the plane is called the *base.*

The *altitude* of a cone is the perpendicular distance from the vertex to the base.

An *element of a cone* is any straight line from the vertex to the circumference of the base.

A *circular cone* is a cone whose base is a circle.

A *right circular cone*, or *cone of revolution*, Fig. 81, is a cone

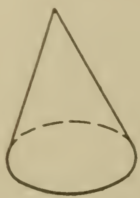

Fig. 80. Cone

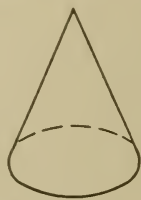

Fig. 81. Right Circular Cone

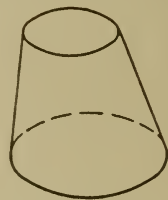

Fig. 82. Frustum of Cone

whose axis is perpendicular to the base. It may be generated by the revolution of a right triangle about one of the legs as an axis.

A *frustum* of a cone, Fig. 82, is the portion of the cone included between the base and a plane parallel to the base; its *altitude* is the perpendicular distance between the bases.

SPHERES

A *sphere* is a solid bounded by a curved surface, every point of which is equally distant from a point within called the *center*.

The *diameter* is a straight line drawn through the center and having its extremities in the curved surface. The *radius*—½ diameter—is the straight line from the center to a point on the surface.

A *plane is tangent to a sphere* when it touches the sphere in only

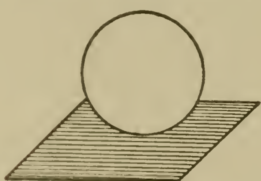

Fig. 83. Plane Tangent to Sphere

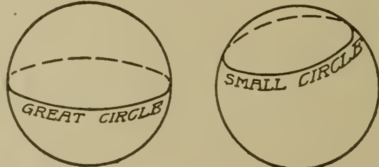

Fig. 84. Great and Small Circle

one point. A plane perpendicular to a radius at its outer extremity is tangent to the sphere, Fig. 83.

An *inscribed polyhedron* is a polyhedron whose vertices lie in the surface of the sphere.

A *circumscribed polyhedron* is a polyhedron whose faces are tangent to a sphere.

A *great circle* is the intersection of the spherical surface and a plane passing through the center of the sphere, Fig. 84.

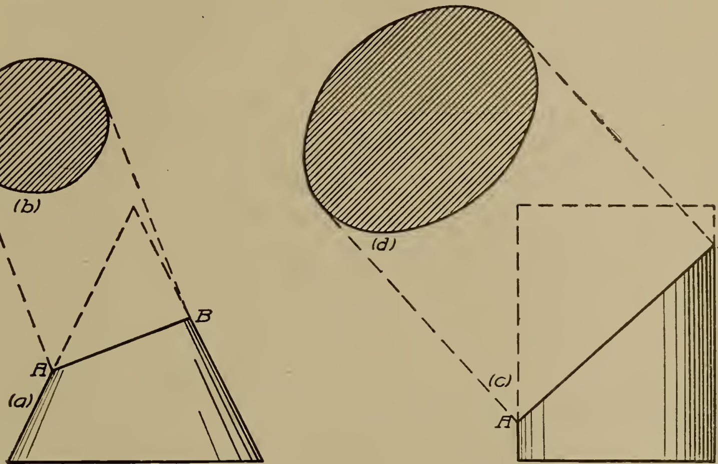

Fig. 85. Intersections of Plane with Cone and Cylinder Giving Ellipses as Shown in (*b*) and (*d*)

A *small circle* is the intersection of the spherical surface and a plane which does not pass through the center, Fig. 84.

CONIC SECTIONS

If a plane intersects a cone at various angles with the base the geometrical figures thus formed are called *conic sections.* A plane perpendicular to the base passing through the vertex of a right circular cone forms an isosceles triangle. If the plane is parallel to the base, the intersection of the plane and the conical surfaces will be the circumference of a circle.

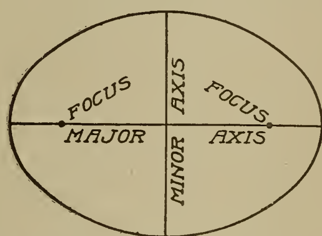

Fig. 86. Diagram Showing Constants of Ellipse

Ellipse. If a plane *AB*, Fig. 85a, cuts a cone oblique to the axis of the cone, but not cutting the base, the curve formed is called an ellipse, as shown in Fig. 85b, this view being taken perpendicular to the plane *AB*. If the plane cuts a cylinder as shown in Fig. 85c, the ellipse shown in Fig. 85d is the result, this view being also taken perpendicular to the plane *AB*. An ellipse may be defined as *a curve generated by a point*

moving in a plane in such a manner that the sum of the distances from the point to two fixed points shall always be constant.

The two fixed points are called *foci,* Fig. 86, and shall lie on the longest line that can be drawn in the ellipse which is called the *major axis;* the shortest line is called the *minor axis;* and is perpendicular to the major axis at its middle point, called the *center.*

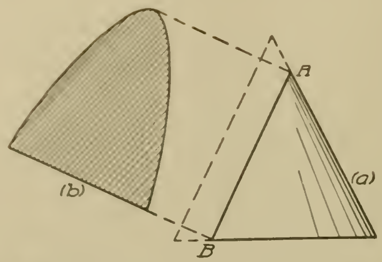

Fig. 87. Intersection of Plane with Cone, Parallel to Element of Cone and Parabolic Section Produced

An ellipse may be constructed if the major and minor axes are given or if the foci and one axis are known.

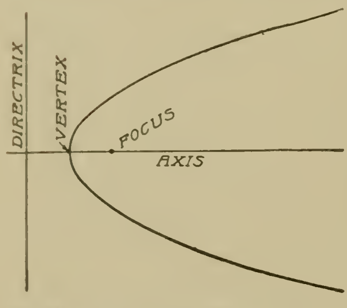

Fig. 88. Diagram Showing Constants of Parabola

Parabola. If a plane *AB,* Fig. 87a, cuts a cone parallel to an element of the cone, the curve resulting from this intersection is called a parabola, as shown in Fig. 87b, the view being taken perpendicular to the plane *AB.* This curve is not a closed curve for the branches approach parallelism.

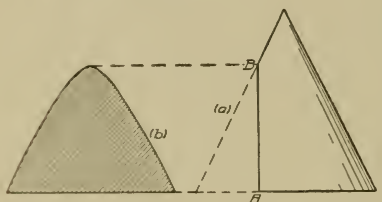

Fig. 89. Intersection of Plane with Cone, Parallel to Axis and Hyperbolic Section Produced

A parabola may be defined as *a curve every point of which is equally distant from a line and a point.*

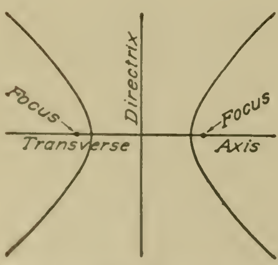

Fig. 90. Diagram Showing Constants of Hyperbola

The point is called the *focus,* Fig. 88, and the given line, the *directrix.* The line perpendicular to the directrix and passing through the focus is the *axis.* The intersection of the axis and the curve is the *vertex.*

Hyperbola. If a plane *AB,* Fig. 89a, cuts a cone parallel to its axis, the resulting curve is called a hyperbola,

Fig. 89b, the view being taken perpendicular to the plane AB.

Like the parabola, the curve is not closed, the branches constantly diverging.

A hyperbola is defined as *a plane curve such that the difference between the distances from any point in the curve to two fixed points is equal to a given distance.*

The two fixed points are the *foci* and the line passing through them is the *transverse axis,* Fig. 90.

Rectangular Hyperbola. The form of hyperbola most used in Mechanical Engineering is called the rectangular hyperbola because it is drawn with reference to rectangular coördinates. This curve is constructed as follows: In Fig. 91, OX and OY are the two coördinate axes drawn at right angles to each other. These lines are also called *asymptotes.* Assume A to be a known point on the curve. Draw AC parallel to OX and AD' perpendicular to OX. Mark off any convenient points on AC such as E, F, G, and H, and through these points draw EE', FF', GG', and HH', perpendicular to OX. Connect E, F, G, H, and C with O. Through the points of intersection of the oblique lines and the vertical line AD' draw the horizontal lines LL', MM', NN', PP', and QQ'. The first point on the curve is the assumed point A, the second point is R, the intersection of LL' and EE', the third the intersection S, and so on.

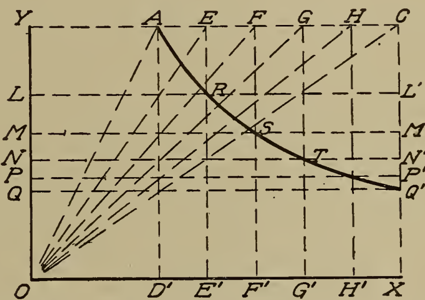

Fig. 91. Construction of Rectangular Hyperbola

In this curve the products of the coördinates of all points are equal. Thus $LR \times RE' = MS \times SF' = NT \times TG'$.

ODONTOIDAL CURVES

Cycloidal Curves. *Cycloid.* The cycloid is a curve generated by a point on the circumference of a circle which rolls on a straight line tangent to the circle, as shown at the left, Fig. 92.

The rolling circle is called the *describing* or *generating circle,* the point on the circle, the *describing* or *generating point,* and the

tangent along which the circle rolls, the *director*. In order that the curve described by the point may be a true cycloid the circle must roll without any slipping.

Hypocycloid. In case the generating circle rolls upon the inside of an arc or circle, the curve thus generated is a hypocycloid,

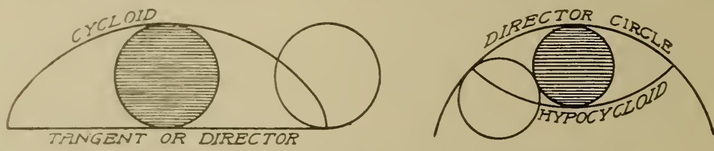

Fig. 92. Geometrical Constructions for Cycloid and Hypocycloid

Fig. 92. If the generating circle has a diameter equal to the radius of the director circle the hypocycloid becomes a straight line.

Epicycloid. If the generating circle rolls upon the *outside* of the *director circle,* the curve generated is an epicycloid, Fig. 93.

Involute Curves. If a thread of fine wire is wound around a cylinder or circle and then unwound, the end will describe an involute curve. The involute may be defined as *a curve generated by a point in a tangent rolling on a circle, known as the base circle,* Fig. 94.

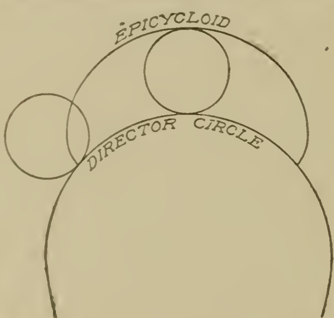

Fig. 93. Geometrical Construction for an Epicycloid

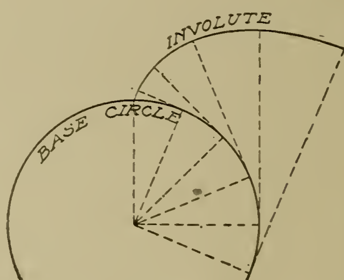

Fig. 94. Geometrical Construction for an Involute

The details of the ellipse, parabola, hyperbola, cycloid, and involute will be taken up in connection with the plates.

The most important application of the cycloidal and involute curves is in the cutting of all forms of gear teeth. It has been found that the teeth of gears when cut accurately to either of these curves will mesh with the least friction and run with exceptional smoothness. The development of these gears and of the machines for cutting them has reached a high state of perfection.

GEOMETRICAL PROBLEMS

The problems given in Plates IV to VIII inclusive have been chosen because of their particular bearing on the work of the mechanical draftsman. They should be solved with great care, as the principles involved will be used in later work.

PLATE IV

Penciling. The horizontal and vertical center lines and the border lines should be laid out in the same manner as in *Plate I.* Now measure off $2\frac{1}{4}$ inches on both sides of the vertical center line and through these points draw vertical lines as shown by the dot and dash lines, *Plate IV.* In locating the figures, place them a little above the center so that there will be room for the number of the problem.

Draw in lightly the lines of each figure with pencil and after the entire plate is completed, ink them. In penciling, all intersections must be formed with great care as the accuracy of the results depends upon it. Keep the pencil points in good order at all times and draw lines *exactly* through intersections.

Problem 1. *To bisect a given straight line.*

Draw the horizontal straight line AC about 3 inches long. With the extremity A as a center and any convenient radius—about 2 inches—describe arcs above and below the line AC. With the other extremity C as a center and with the same radius draw similar arcs intersecting the first arcs at D and E. The radius of these arcs must be greater than one-half the length of the line in order that they may intersect. Now draw the straight line DE passing through the intersections D and E. This line will cut AC at its middle point F.
Therefore

$$AF = FC$$

Proof. Since the points D and E are equally distant from A and C a straight line drawn through them is perpendicular to AC at its middle point F.

Problem 2. *To construct an angle equal to a given angle.*

Draw the line OC about 2 inches long and the line OA of about the same length. The angle formed by these lines may be

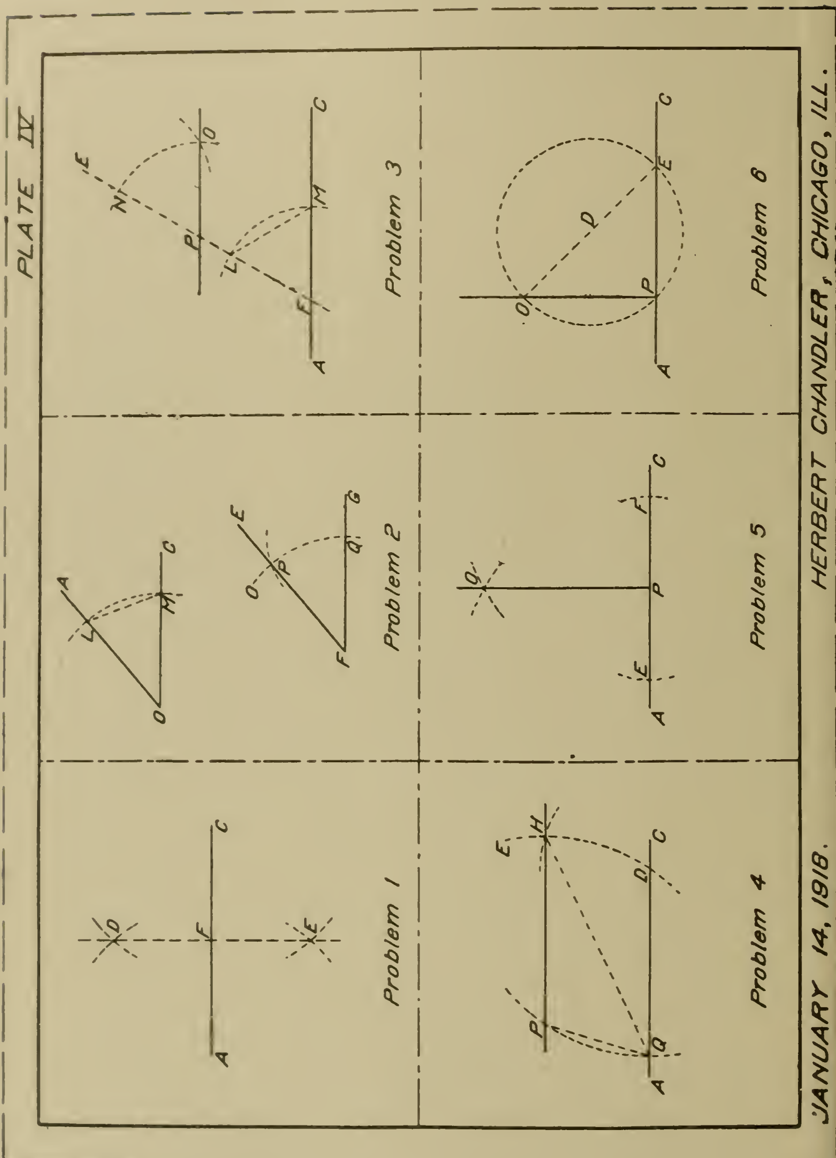
PLATE IV
Problem 1
Problem 2
Problem 3
Problem 4
Problem 5
Problem 6
JANUARY 14, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

any convenient size—about 45 degrees is suitable. This angle $A\ O\ C$ is the given angle.

Now draw $F\,G$, a horizontal line about $2\frac{1}{4}$ inches long, and let F, the left-hand extremity, be the vertex of the angle to be constructed

With O as a center and any convenient radius—about $1\frac{1}{2}$ inches—describe the arc $L\ M$ cutting both $O\ A$ and $O\ C$. With F as a center and the same radius draw the indefinite arc $O\ Q$. Now set the compass so that the distance between the pencil and the needle point is equal to the chord $L\ M$. With Q as a center and a radius equal to $L\ M$ draw an arc cutting the arc $O\ Q$ at P. Through F and P draw the straight line $F\ E$. The angle $E\ F\ G$ is the required angle since it is equal to $A\ O\ C$.

Proof. Since the chords of the arcs $L\ M$ and $P\ Q$ are equal, the arcs are equal. The angles are equal because with equal radii equal arcs are intercepted by equal angles.

Problems 3 and 4. *To draw through a given point a line parallel to a given line.*

First Method. Draw the straight line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. Through the point P draw an oblique line $F\ E$ forming any convenient angle—about 60 degrees—with $A\ C$. Now construct an angle equal to $P\ F\ C$ having its vertex at P and the line $E\,P$ as one side. (See Problem 2.) The straight line $P\ O$ forming the other side of the angle $E\,P\ O$ will be parallel to $A\ C$.

Proof. If two straight lines are cut by a third making the corresponding angles equal, the lines are parallel.

Second Method. Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. With P as a center and any convenient radius—about $2\frac{1}{2}$ inches—draw the indefinite arc $E\ D$ cutting the line $A\ C$. Now with the same radius and with D as a center, draw an arc $P\ Q$. Set the compass so that the distance between the needle point and the pencil is equal to the chord $P\ Q$. With D as a center and a radius equal to $P\ Q$, describe an arc cutting the arc $E\ D$ at H. A line drawn through P and H will be parallel to $A\ C$.

Proof. Draw the line $Q\ H$. Since the arcs $P\,Q$ and $H\ D$ are equal and have the same radii, the angles $P\ H\ Q$ and $H\ Q\ D$

are equal. Two lines are parallel if the alternate interior angles are equal.

Problems 5 and 6. *To draw a perpendicular to a line from a point in the line.*

First Method. WHEN THE POINT IS NEAR THE MIDDLE OF THE LINE.

Draw the line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P near the middle of the line. With P as a center and any convenient radius—about $1\frac{1}{4}$ inches—draw two arcs cutting the line $A\ C$ at E and F. Now with E and F as centers and any convenient radius —about $2\frac{1}{2}$ inches—describe arcs intersecting at O. The line $O\ P$ will be perpendicular to $A\ C$ at P.

Proof. The points P and O are both equally distant from E and F. Hence a line drawn through them is perpendicular to $E\ F$ at P.

Second Method. WHEN THE POINT IS NEAR THE END OF THE LINE.

Draw the line $A\ C$ about $3\frac{1}{2}$ inches long. Assume the given point P to be about $\frac{3}{4}$ inch from the end A. With any point D as a center and a radius equal to $D\ P$, describe an arc cutting $A\ C$ at E. Through E and D draw the diameter $E\ O$. A line from O to P is perpendicular to $A\ C$ at P.

Proof. The angle $O\ P\ E$ is inscribed in a semicircle; hence it is a right angle, and the sides $O\ P$ and $P\ E$ are perpendicular to each other.

Lettering. After completing these figures draw pencil lines for the lettering. Place the words "*Plate IV*" and the date and the name in the border, as in preceding plates. To letter the words "Problem 1," "Problem 2," etc., draw three horizontal lines $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, and $\frac{7}{16}$ inch, respectively, above the horizontal center line and the lower border line to serve as a guide for the size of the letters.

Inking. In inking *Plate IV*, ink in the figures first. Make the line $A\ C$, Problem 1, a full line as it is the given line; make the arcs and the line $D\ E$ dotted as they are construction lines. Similarly in Problem 2, make the sides of the angles full lines and the chord $L\ M$ and the arcs dotted. Follow the same plan in inking the lines of Problems 3, 4, 5, and 6. In Problem 6, ink in only that part of the circumference which passes through the points O, P, and E.

After inking the figures, ink in the heavy border line, and the lettering.

PLATE V

Penciling. In laying out the border lines and center lines follow the directions given for *Plate IV.* Draw the dot and dash lines in the same manner, as there are to be six problems on this plate.

Problem 7. *To draw a perpendicular to a line from a point without the line.*

Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long, and assume the point P about $1\frac{1}{2}$ inches above the line. With P as a center and any convenient radius—about 2 inches—describe an arc cutting $A\ C$ at E and F. The radius of this arc must always be such that it will cut $A\ C$ in two points; the nearer the points E and F are to A and C, the greater will be the accuracy of the work.

Now with E and F as centers and any convenient radius—about $2\frac{1}{4}$ inches—draw the arcs intersecting below $A\ C$ at T. A line through the points P and T will be perpendicular to $A\ C$. In case there is not room below $A\ C$ to draw the arcs, they may be drawn intersecting above the line as shown at N. Whenever convenient draw the arcs below $A\ C$ for greater accuracy.

Proof. Since P and T are both equally distant from E and F, the line $P\ T$ is perpendicular to $A\ C$.

Problems 8 and 9. *To bisect a given angle.*

First Method. WHEN THE SIDES INTERSECT.

Draw the lines $O\ C$ and $O\ A$—about 3 inches long—forming any angle of 45 to 60 degrees. With O as a center and any convenient radius—about 2 inches—draw an arc intersecting the sides of the angle at E and F. With E and F as centers and a radius of $1\frac{1}{2}$ or $1\frac{3}{4}$ inches, describe short arcs intersecting at I. A line $O\ D$, drawn through the points O and I, bisects the angle.

In solving this problem the arc $E\ F$ should not be too near the vertex if accuracy is desired.

Proof. The central angles $A\ O\ D$ and $D\ O\ C$ are equal because the arc $E\ F$ is bisected by the line $O\ D$. The point I is equally distant from E and F.

Second Method. WHEN THE LINES DO NOT INTERSECT.

Draw the lines $A\ C$ and $E\ F$ about 4 inches long making an

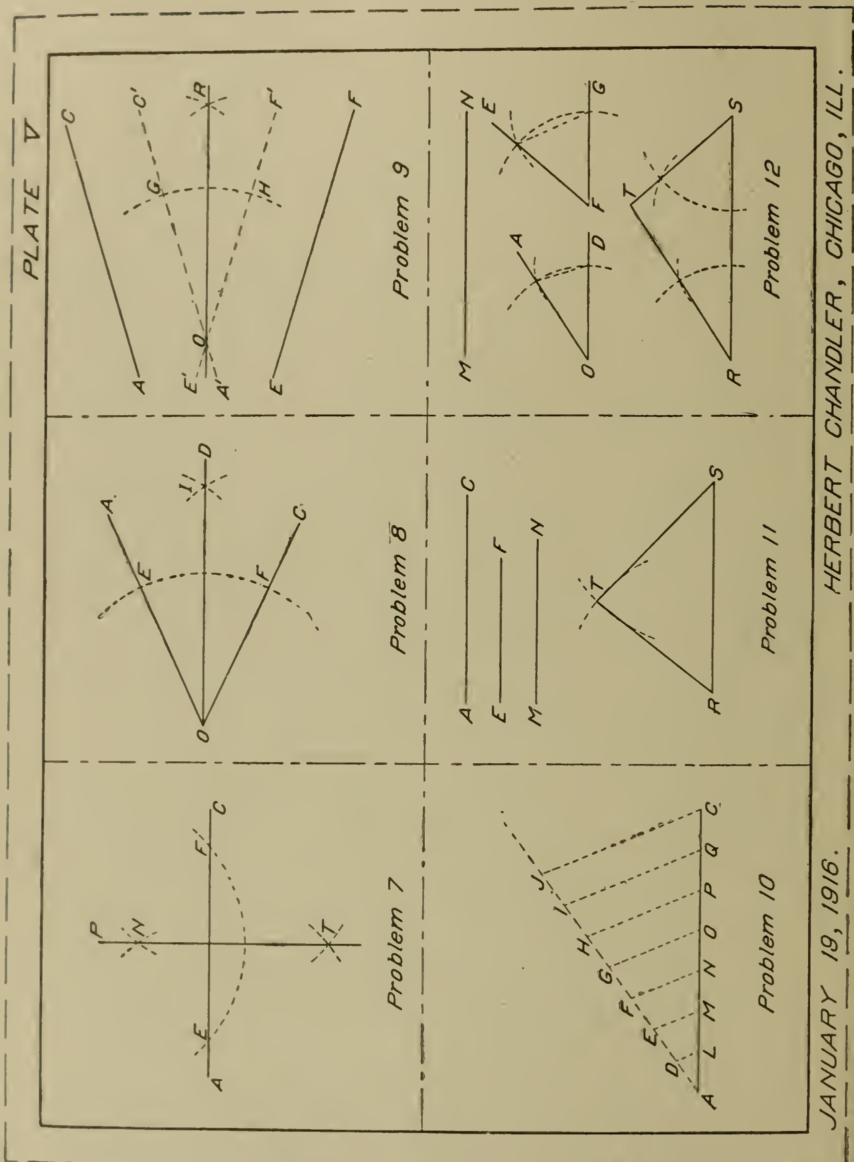
PLATE V
Problem 7
Problem 8
Problem 9
Problem 10
Problem 11
Problem 12
JANUARY 19, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

angle approximately as shown. Draw $A' C'$ and $E' F'$ parallel to $A C$ and $E F$ and at such equal distances from them that they will intersect at O. Now bisect the angle $C' O F'$ by the method given in Problem 8. The line $O R$ bisects the given angle.

Proof. Since $A' C'$ is parallel to $A C$ and $E' F'$ is parallel to $E F$, the angle $C' O F'$ is equal to the angle formed by the lines $A C$ and $E F$. Hence as $O R$ bisects angle $C' O F'$ it also bisects the angle formed by the lines $A C$ and $E F$.

Problem 10. *To divide a line into any number of equal parts.*

Let $A C$—about $3\frac{3}{4}$ inches long—be a given line. Suppose it is desired to divide it into 7 equal parts. First draw the line $A J$ at least 4 inches long, forming any convenient angle with $A C$. On $A J$ lay off, by means of the dividers or scale, points D, E, F, G, etc., each $\frac{1}{2}$ inch apart. (If dividers are used, the spaces need not be exactly $\frac{1}{2}$ inch.) Draw the line $J C$ and through the points D, E, F, G, etc., draw lines parallel to $J C$. These parallels will divide the line $A C$ into 7 equal parts.

Proof. If a series of parallel lines, cutting two straight lines, intercept equal distances on one of these lines, they also intercept equal distances on the other.

Problem 11. *To construct a triangle having given the three sides.*

Draw the three sides, $A C$, $2\frac{3}{4}$ inches long; $E F$, $1\frac{15}{16}$ inches long; and $M N$, $2\frac{3}{16}$ inches long.

Draw $R S$ equal in length to $A C$. With R as a center and a radius equal to $E F$ describe an arc. With S as a center and a radius equal to $M N$ draw an arc cutting the arc previously drawn, at T. Connect T with R and S to form the triangle.

Problem 12. *To construct a triangle having given one side and the two adjacent angles.*

Draw the line $M N$ $3\frac{1}{4}$ inches long and draw two angles $A O D$ and $E F G$ about 30 degrees and 60 degrees respectively.

Draw $R S$ equal in length to $M N$ and with R as a vertex and $R S$ as one side construct an angle equal to $A O D$. In a similar manner construct at S an angle equal to $E F G$. Draw lines from R and S through the two established points until they meet at T. The triangle $R T S$ will be the required triangle.

Lettering. Draw the pencil lines and put in the lettering as in plates already drawn.

Inking. In inking *Plate V*, follow the principles previously used and do not make certain lines dotted until sure that they should be dotted.

After inking the figures, ink in the border lines and the lettering as already explained.

PLATE VI

Penciling. Lay out this plate in the same manner as the preceding plates.

Problem 13. *To describe an arc or circumference through three given points not in the same straight line.*

Locate the three points A, B, and C with a distance between A and B of about 2 inches and a distance between A and C of about $2\frac{1}{4}$ inches. Connect A and B and A and C. Erect perpendiculars to the middle points of $A B$ and $A C$ as explained in Problem 1. Now draw light pencil lines connecting the intersections I and J and E and F. These lines will intersect at O.

With O as a center and a radius equal to the distance $O A$, describe the circumference passing through A, B, and C.

Proof. The point O is equally distant from A, B, and C, since it lies in the perpendiculars to the middle points of $A B$ and $A C$. Hence the circumference will pass through A, B, and C.

Problem 14. *To inscribe a circle in a given triangle.*

Draw the triangle $L M N$ of any convenient size. $M N$ may be made $3\frac{1}{4}$ inches, $L M$, $2\frac{3}{4}$ inches, and $L N$, $3\frac{1}{2}$ inches. Bisect the angles $M L N$ and $L M N$ by the method used in Problem 8. The bisectors $M I$ and $L J$ intersect at O, which is the center of the inscribed circle. The radius of the circle is equal to the perpendicular distance from O to one of the sides.

Proof. The point of intersection of the bisectors of the angles of a triangle is equally distant from the sides.

Problem 15. *To inscribe a regular pentagon in a given circle.*

With O as a center and a radius of about $1\frac{1}{2}$ inches, describe the given circle. With the T-square and triangles draw the center lines $A C$ and $E F$ perpendicular to each other and passing through O. Bisect one of the *radii*, $O C$, at H and with this point as a center and a radius $H E$, describe the arc $E P$. This arc cuts the diameter $A C$ at P. With E as a center and a radius $E P$, draw arcs cutting

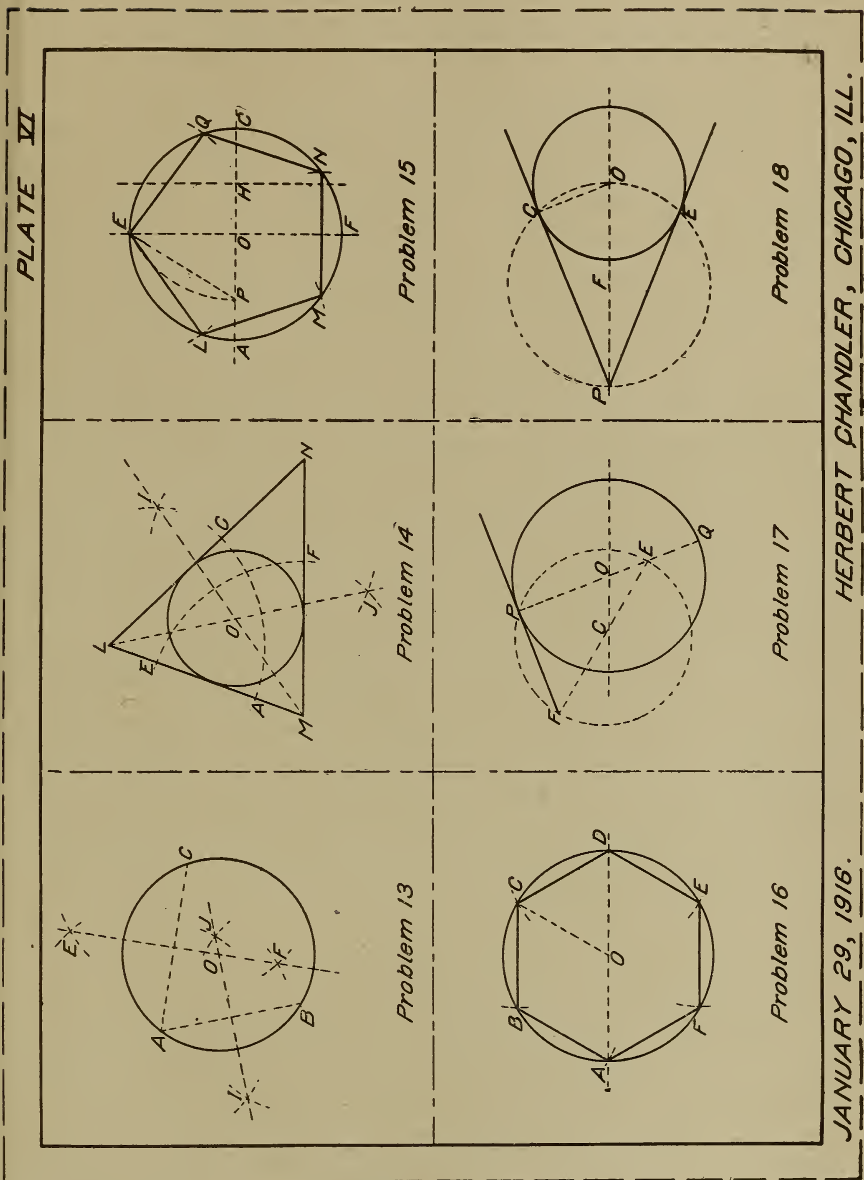
PLATE VII
Problem 15
Problem 14
Problem 13
Problem 18
Problem 17
Problem 16
JANUARY 29, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the circumference at L and Q. With the same radius and centers at L and Q, draw the arcs cutting the circumference at M and N.

The pentagon is completed by drawing the chords $E\,L$, $L\,M$, $M\,N$, $N\,Q$, and $Q\,E$.

Problem 16. *To inscribe a regular hexagon in a given circle.*

With O as a center and a radius of $1\frac{3}{8}$ inches draw the given circle. With the T-square draw the diameter $A\,D$. With D as a center, and a radius equal to $O\,D$, describe arcs cutting the circumference at C and E. Now with C and E as centers and the same radius, draw the arcs, cutting the circumference at B and F. Draw the hexagon by joining the points thus formed.

Therefore, in order to inscribe a regular hexagon in a circle, mark off chords equal in length to the radius.

To inscribe an equilateral triangle in a circle the same method may be used, the triangle being formed by joining the opposite vertices of the hexagon.

Proof. Since the triangle $O\,C\,D$ is an equilateral triangle by construction, the angle $C\,O\,D$ is one-third of two right angles and one-sixth of four right angles. Hence arc $C\,D$ is one-sixth of the circumference and the chord is a side of a regular hexagon.

Problem 17. *To draw a line tangent to a circle at a given point on the circumference.*

With O as a center and a radius of about $1\frac{1}{4}$ inches draw the given circle. Assume some point P on the circumference and join the point P with the center O. By the method given in Problem 6, *Plate IV*, construct a perpendicular to $P\,O$, which perpendicular will be the desired tangent to the circle at the point P.

Proof. A line perpendicular to a radius at its extremity is tangent to the circle.

Problem 18. *To draw a line tangent to a circle from a point outside the circle.*

With O as a center and a radius of about 1 inch draw the given circle. Assume P some point outside of the circle about $2\frac{1}{2}$ inches from the center. Draw a straight line passing through P and O. Bisect $P\,O$ and with the middle point F as a center describe the circle passing through P and O. Draw a line from P through the intersection of the two circumferences C. The line $P\,C$ is tangent to the given circle. Similarly $P\,E$ is tangent to the circle.

Proof. The angle $P\,C\,O$ is inscribed in a semicircle and hence is a right angle. Since $P\,C\,O$ is a right angle, $P\,C$ is perpendicular to $C\,O$. The perpendicular to a radius at its extremity is tangent to the circumference.

Inking. In inking *Plate VI,* the same method should be followed as in previous plates.

PLATE VII

Penciling. Lay out this plate in the same manner as the preceding plates.

Problems 19 and 20. *To draw an ellipse when the axes are given.*

First Method. Draw the lines $L\,M$ and $C\,D$ about $3\frac{1}{4}$ and $2\frac{1}{4}$ inches long respectively, making $C\,D$ perpendicular to $L\,M$ at its middle point P and having $C\,P = P\,D$. The two lines, $L\,M$ and $C\,D$, are the axes. With C as a center and a radius $L\,P$ equal to one-half the major axis, draw the arc, cutting the major axis at E and F. These two points are the foci.

Now locate several points on $P\,M$, such as A, B, and G. With E as a center and a radius equal to $L\,A$, draw arcs above and below $L\,M$. With F as a center and a radius equal to $A\,M$ describe short arcs cutting those already drawn as shown at N. With E as a center and a radius equal to $L\,B$ draw arcs above and below $L\,M$ as before. With F as a center and a radius equal to $B\,M$, draw arcs intersecting those already drawn as shown at O. The point R and others are found by repeating the process. The student is advised to find at least 12 points on the curve—6 above and 6 below $L\,M$. These 12 points with L, C, M, and D will enable him to draw the curve.

After locating these points, draw a free-hand curve passing through them.

Second Method. Draw the two axes $A\,B$ and $P\;\;Q$ in the same manner as in the first method. With O as a center and a radius equal to one-half the major axis, describe a circle. Similarly with the same center and a radius equal to one-half the minor axis, describe another circle. Draw any radii such as $O\,C$, $O\,D$, $O\,E$, $O\,F$, etc., cutting both circumferences. These radii may be drawn with the 60 and 45 degree triangles. From C, D, E, and F, the points of intersection of the radii with the large circle, draw *vertical* lines and from C', D', E', and F' the points of intersection of the radii with

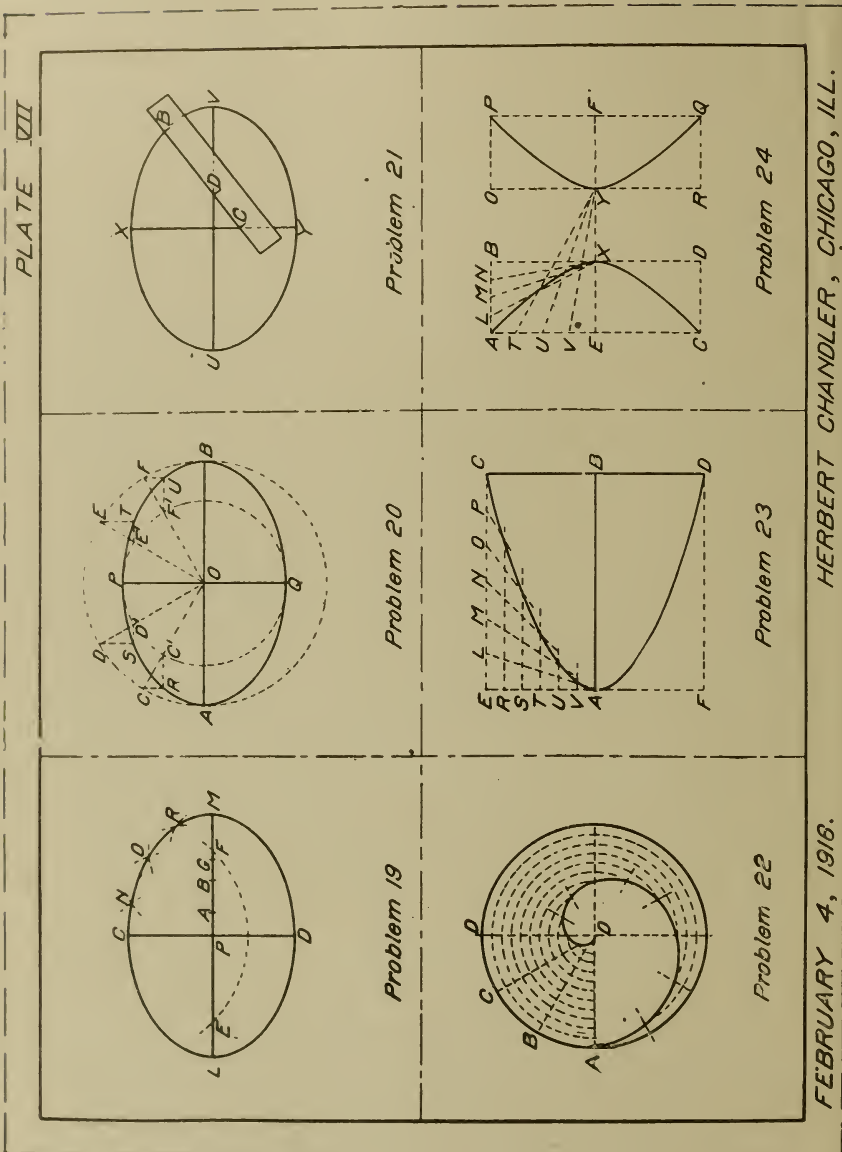
PLATE VII
Problem 19
Problem 20
Problem 21
Problem 22
Problem 23
Problem 24
FEBRUARY 4, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the small circle, draw *horizontal* lines The intersections of these lines are points on the ellipse.

Draw a free-hand curve* passing through these points; about five points in each quadrant will be sufficient.

Problem 21. *To draw an ellipse by means of a trammel.*

As in Problems 19 and 20, draw the major and minor axes, *U V* and *X Y*. Take a slip of paper having a straight edge and mark off *C B* equal to one-half the major axis, and *D B* equal to one-half the minor axis. Place the slip of paper in various positions keeping the point *D* on the major axis and the point *C* on the minor axis. If this is done, the point *B* will mark various points on the curve. Find as many points as necessary and sketch the ellipse.

Problem 22. *To draw a spiral of one turn in a circle.*

Draw a circle with the center at *O* and a radius of $1\frac{1}{2}$ inches. Locate twelve points, $\frac{1}{8}$ inch apart on the radius *O A* and draw circles through these points. With the 30-degree triangle, draw radii *OB, OC, OD,* etc., 30 degrees apart, thus forming 12 equal parts.

The points on the spiral are now located; the first is at the center *O;* the next is at the intersection of the line *O B* and the first circle; the third is at the intersection of *O C* and the second circle; the other points are located in the same way. Sketch in pencil a smooth curve passing through these points.

Problem 23. *To draw a parabola when the abscissa and ordinate are given.*

Draw the straight line *A B*—about three inches long—as the axis, or *abscissa* of the parabola. At *A* and *B* draw the lines *E F* and *C D* perpendicular to *A B,* and with the T-square draw *E C* and *F D,* $1\frac{1}{2}$ inches above and below *A B,* respectively. Let *A* be the vertex of the parabola. Divide *A E* and *E C* into the same number of equal parts. Through *R, S, T, U,* and *V,* draw horizontal lines and connect *L, M, N, O,* and *P,* with *A*. The intersections of the horizontal lines with the oblique lines are points on the curve. For instance, the intersection of *A L* and the line *V* is one point and the intersection of *A M* and the line *U* is another.

The lower part of the curve *A D* is drawn in a similar manner.

Problem 24. *To draw a hyperbola when the abscissa E X, the ordinate A E, and the diameter X Y are given.*

*See Page 16, Mechanical Drawing, Part I.

Draw E F about 3 inches long and mark the point X, 1 inch from E and the point Y, 1 inch from X. With the triangle and T-square, draw the rectangles A B D C and O P Q R such that A B is 1 inch in length and A C, 3 inches in length. Divide A E and A B into the same number of equal parts. Connect Y with the points T, U, and V, on A E, and connect X with L, M, and N, on A B. The first point on the curve is at A; the next is at the intersection of T Y and L X; the third is at the intersection of U Y and M X. The remaining points are found in the same manner. Repeat the process for X C and the right-hand curve P Y Q.

Inking. In inking the figures on this plate, use the French or irregular curve and make full lines for the curves and their axes. Dot the construction lines as usual. Ink in all the construction lines used in finding one-half of a curve, and in Problems 19, 20, 23, and 24 leave all construction lines in *pencil* except those inked. In Problems 21 and 22 erase all construction lines not inked. The trammel used in Problem 21 may be drawn in the position shown, or outside of the ellipse in any convenient place.

The same lettering should be done on this plate as on previous plates

PLATE VIII

Penciling. In laying out *Plate VIII*, draw the border lines and horizontal and vertical center lines as in previous plates, dividing the plate into four spaces.

Problem 25. *To construct a cycloid when the diameter of the generating circle is given.*

With O' as a center and a radius of $\frac{7}{8}$ inch draw a circle, and, tangent to it, draw the indefinite horizontal straight line A B. Divide the circle into any number of equal parts—12 for instance—and through these points of division C, D, E, F, etc., draw horizontal lines. Now with the dividers set so that the distance between the points is equal to the chord of the arc C D, mark off the points L, M, N, O, P, on the line A B, commencing at the point H. At these points erect perpendiculars to the center line X O' which is the line of centers of the generating circle as it rolls along the line A B. With the intersections Q, R, S, T, etc., as centers describe arcs of circles as shown. The points on the cycloid will be the intersections of

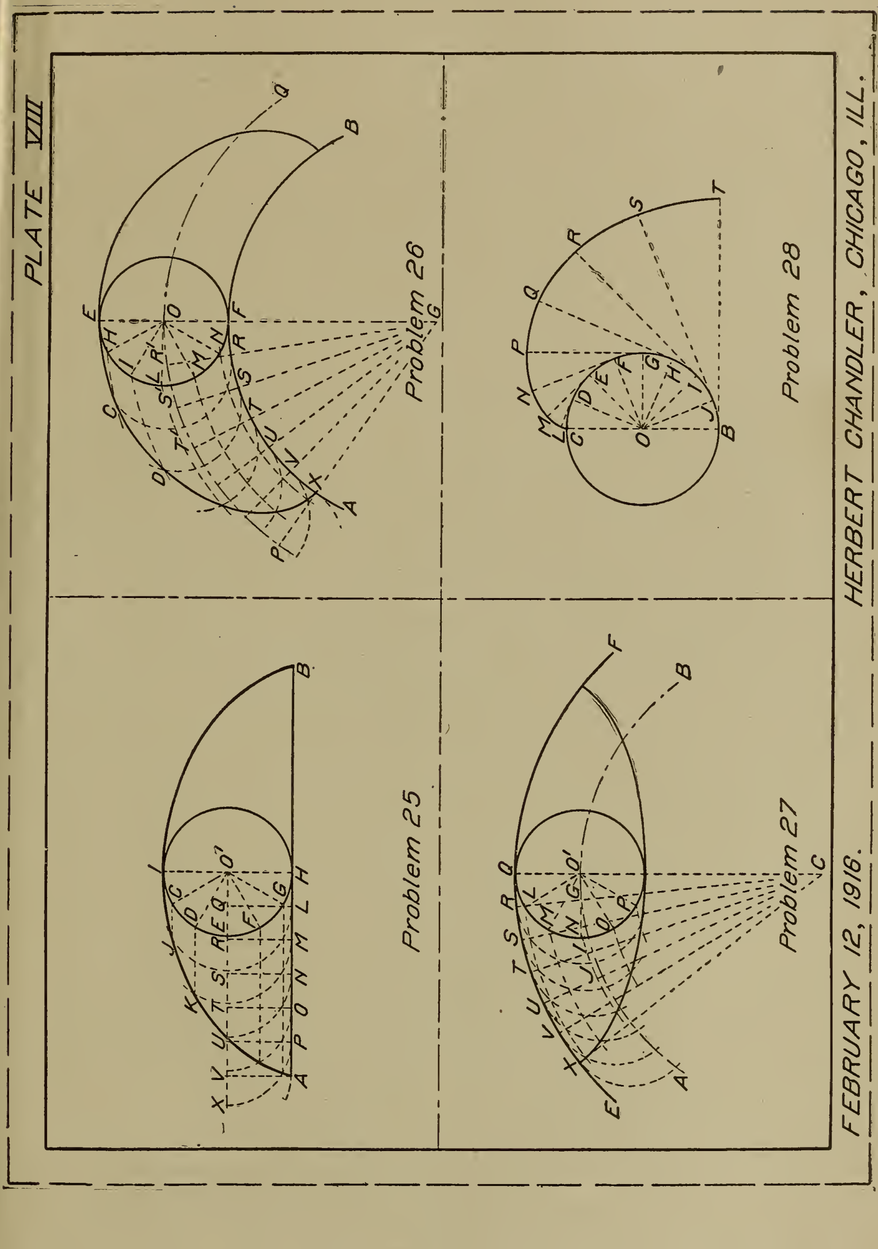
PLATE VIII
Problem 26
Problem 28
Problem 25
Problem 27
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 12, 1916.

these arcs and the horizontal lines drawn through the points C, D, E, F, etc. Thus the intersection of the arc whose center is Q and the horizontal line through C is a point J on the curve. Similarly, the intersection of the arc whose center is R and the horizontal line through D is the point K on the curve. The remaining points on the left, as well as those on the right, are found in the same manner. To obtain great accuracy in this curve, the circle should be divided into a large number of equal parts, because the greater the number of divisions the less the error due to the difference in length between a chord and its arc.

Problem 26. *To construct an epicycloid when the diameter of the generating circle and the diameter of the director circle are given.*

The epicycloid and the hypocycloid may be drawn in the same manner as the cycloid if arcs of circles are used in place of the horizontal lines. With O as a center and a radius of $\frac{3}{4}$ inch describe a circle. Draw the diameter $E\ F$ of this circle and produce $E\ F$ to G such that the line $F\ G$ is $2\frac{3}{4}$ inches long. With G as a center and a radius $F\ G$, describe the arc $A\ B$ of the director circle. With the same center G, draw the arc $P\ Q$ which will be the path of the center of the generating circle as it rolls along the arc $A\ B$. Now divide the generating circle into any number of equal parts—twelve for instance—and through the points of division H, I, L, M, and N, draw arcs having G as a center. With the dividers set so that the distance between the points is equal to the chord $H\ I$, mark off distances on the director circle $A\ F\ B$. Through these points of division R, S, T, U, etc., draw radii intersecting the arc $P\ Q$ in the points R', S', T', etc., and with these points as centers describe arcs of circles as in Problem 25. The intersections of these arcs with the arcs already drawn through the points H, I, L, M, etc., are points on the epicycloid. Thus the intersection of the circle whose center is R' with the arc drawn through the point H is a point upon the curve. Also the arc whose center is S' with the arc drawn through the point I is another point on the curve. The remaining points are found by repeating this process.

Problem 27. *To draw an hypocycloid when the diameter of the generating circle and the radius of the director circle are given.*

With C as a center and a radius of 4 inches describe the arc $E\ F$, which is the arc of the director circle. Now with the same

center and a radius of $3\frac{1}{4}$ inches, describe the arc *A B*, which is the line of centers of the generating circle as it rolls on the director circle. With O' as a center and a radius of $\frac{3}{4}$ inch describe the generating circle. As before, divide the generating circle into any number of equal parts—12, for instance—and with these points of division *L, M, N, O*, etc., draw arcs having *C* as a center. Upon the arc *E F*, lay off distances *Q R, R S, S T*, etc., equal to the chord *Q L*. Draw radii from the points *R, S, T*, etc., to the center of the director circle *C* and describe arcs of circles having a radius equal to the radius of the generating circle, using the points *G, I, J*, etc., as centers. As in Problem 26, the intersections of the arcs are the points on the hypocycloid. By repeating this process, the right-hand portion of the curve may be drawn.

Problem 28. *To draw the involute of a circle when the diameter of the base circle is known.*

With the point *O* as a center and a radius of 1 inch, describe the base circle. Divide the circle into any number of equal parts—16, for instance—and draw radii to the points of division. At the point *D*, draw a light pencil line perpendicular to *O D*. This line will be tangent to the circle. Similarly at the points *E, F, G, H*, etc., draw tangents to the circle. Set the dividers so that the distance between the points will be equal to the chord of the arc *C D*, and measure this distance from *D* along the tangent. From the point *E*, measure on the tangent a distance equal to two of these chords; from the point *F*, three divisions; and from the point *G*, four divisions. Similarly, measure distances on the remaining tangents, each time adding the length of the chord. This will give the points *L, M, N, P*, etc., to *T*. The curve drawn through these points will be the involute of the circle.

Inking. Observe the same rules in inking *Plate VIII* as were given for *Plate VII*. In Problems 25 and 26 the arcs and lines used in locating the points of the other half of the curve may be left in pencil. In Problem 28, all construction lines should be inked. After completing the problems the same lettering should be done on this plate as on previous plates.

LONGITUDINAL SECTION THROUGH MUSIC BUILDING FOR DOANE COLLEGE, CRETE, NEBRASKA

Dean and Dean, Architects, Chicago, Illinois

MECHANICAL DRAWING

PART III

PROJECTIONS

ORTHOGRAPHIC PROJECTION

Definitions. *Projection.* The word projection means *to throw forward.* In mechanical drawing, the significance is *to throw forward in straight lines.* Projection really means, therefore, either the act or the result of projecting parallel rays from the surface of a body and of cutting these rays with a plane, so as to obtain on the

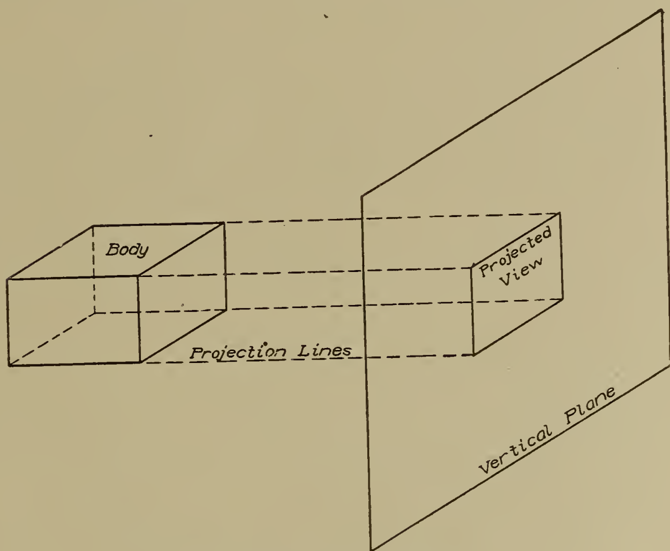

Fig. 95. Body and Its Projection

plane a shape corresponding point for point with that of the body. The rays are called *projecting lines.* A plane may be considered transparent, since it is a flat surface having no thickness.

View. In Fig. 95 a body is shown as projecting from its surface projection lines, and these lines are cut by a plane. By connecting the points on the plane made by the projection lines the

projection of the body is formed, and it corresponds in shape with the body itself. A projection of this kind is called a *view*, this name being given it on account of the fact that an observer on the same side of the body as the projection plane would get this view.

It can readily be seen that one view only will not give a complete picture of a solid object. Usually two or more views are necessary, according to the complication of the object or body. When two or three views are shown, they are pictured on two or three planes at right angles to each other. In this way views of two or three sides are shown, and this is usually sufficient to give the idea of the complete form of the object.

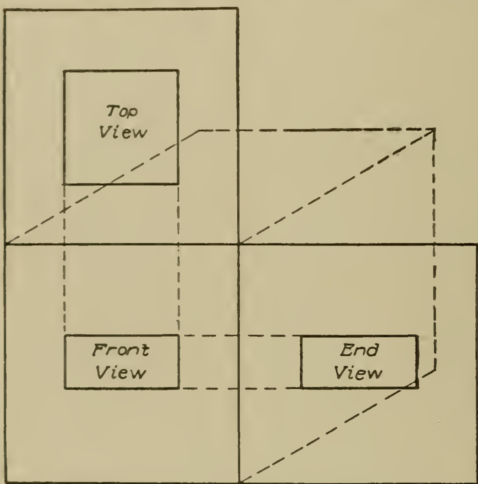

Fig. 96. Projections of Top, Front, and End of Body

Orthographic. The word *orthographic* means at right angles, and in mechanical drawing, in connection with the word projection, it means that two or more views are projected on planes at right angles with each other. The various views of a body have special names—those showing vertical faces are called *elevations,* such as front, side, end or rear elevation; a view of the top of a body is called a *plan* or *plan view;* and a view of the under side, a *bottom view.*

Third-Angle Projection. In Fig. 96 is shown three faces of a body projected on three planes—the top view on the top plane, the front view on the front plane, and the end view on the end plane. It will be seen that the same body is represented as projecting rays in three directions, and thus the three projections, or views, are obtained. It will also be seen that the three planes with their views have been brought into one plane, that is, the surface of the paper. This brings the top view directly above the front view, and the end view to the right of the front view. The above is a definition of

true projection, usually called *third-angle projection,* and is the method used by practically all draftsmen in this country.

First-Angle Projection. There is, however, a method called first-angle projection, used but little now in this country, although formerly in almost general use. Because draftsmen may have to do at times with old drawings or drawings made in foreign countries, it is well for them to understand first-angle projection. This method

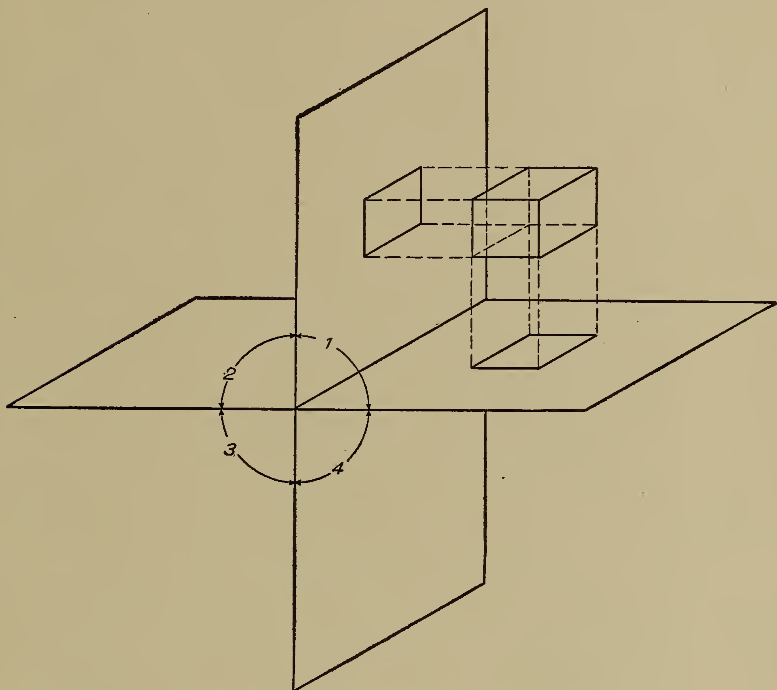

Fig. 97. Body and Its First-Angle Projections

brings the front view, or elevation, above the top view, or plan, the end view being at the right of the front view. Fig. 97 shows this method of first-angle projection.

Comparison of Third- and First-Angle Projection. Perhaps a short explanation will make clear the meaning of third- and first-angle projection. In geometry, when two planes intersect at right angles, the angles are designated as first, second, third, and fourth, as numbered in Fig. 97. In first-angle projection, the body is placed in angle 1, and a top view is projected on a plane under the body

This passes the projection lines back through the body, instead of throwing them out from the surface. In fact, by this method, the body is supposed to turn itself inside out, an absurdity which led to the general abandonment of the method in this country. Third-angle projection places a body in angle 3, and projects a top view on to the plane above it, and a front view on to the plane in front of it. This is true projection.

Projection Methods. When a drawing is made by projection, an object is represented just as it would be seen if one eye were closed and the other were directly over each point of the object at the same time. As an illustration of this, place a box on a table and a piece of ground glass a few inches in front of it. Now, stand

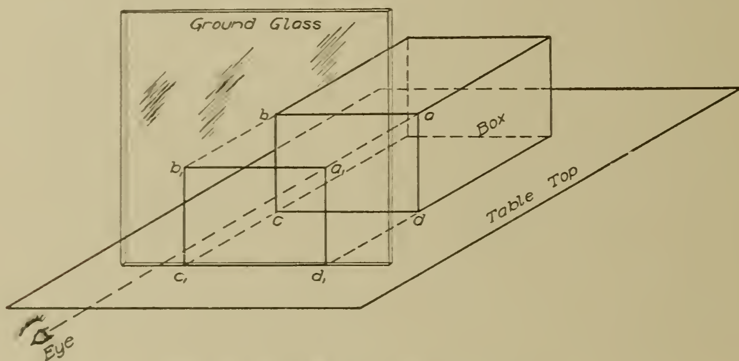

Fig. 98. Visual Method of Finding Projection

so that one eye will come directly in line with one corner a, Fig. 98. Make a dot at a_1 where the line from the eye to the corner a passes through the glass. Next, move the eye until it is directly in line with the corner b of the box, and put a dot at b_1 where the line from the eye to the corner b passes through the glass. Repeat this process, putting dots on the glass at c_1 and d_1 where the lines from the eye to the corners c and d pass through the glass. Now, connect the points a_1, b_1, c_1, and d_1, and the complete projection of the front of the box will be shown by the figure on the glass. This

NOTE. The first four figures in this textbook, Figs. 95, 96, 97, and 98, are pictorial views given to show the student clearly how the views of objects are projected. The student in drawing orthographic projections does not need to draw the pictorial views, but simply the projections, as illustrated in Figs. 99 to 129, inclusive.

figure is a rectangle, and is the same shape and size as the front of the box.

It is readily seen that from this one projection drawing, or view, no idea of the depth of the box is given, although the width and height are correctly shown. A top, or plan, view must now be made to show the depth of the box. Place another piece of ground glass a few inches above the box and, with the eye directly over each separate corner of the top, repeat the process of making the four dots, representing each top corner. Connect these four dots, and the figure thus formed represents the top projection, or plan view, of the box. Now, arrange the two pieces of glass, as shown in Fig. 99. The box being removed, the upper glass is simply lowered to the table, and the front glass is turned from the bottom forward and up, and laid directly below the upper glass.

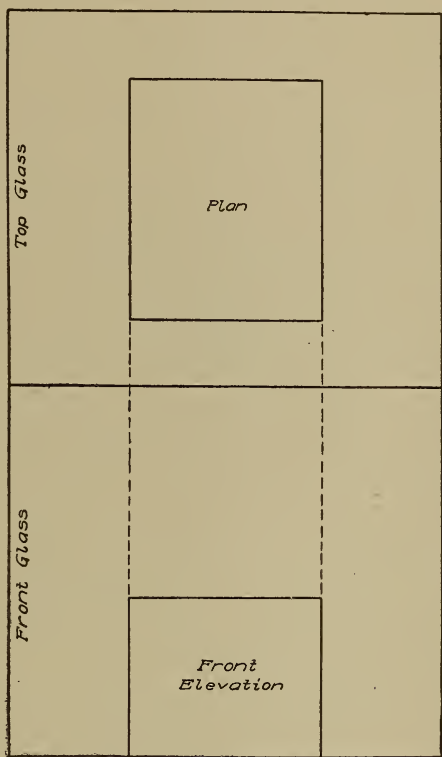

Fig. 99. Plan and Elevation of Box Shown in Fig. 98

This position of the figures represents the two projections—front elevation and plan—just as they would be drawn by a draftsman on a sheet of drawing paper. The width of the box is shown in both views, and being the same in each, the front elevation and plan are both of equal width, and therefore each point in the plan is directly over the corresponding point in the front elevation. In more complicated objects, where the complete idea cannot be obtained from the front elevation and plan views, an end view or both end views must be shown as in Fig. 100, which represents the projections of a box with a curved top. These end views are obtained by taking two or more

pieces of ground glass, placing them one in front of each end, and then drawing the projections. This is done, as in the cases of the

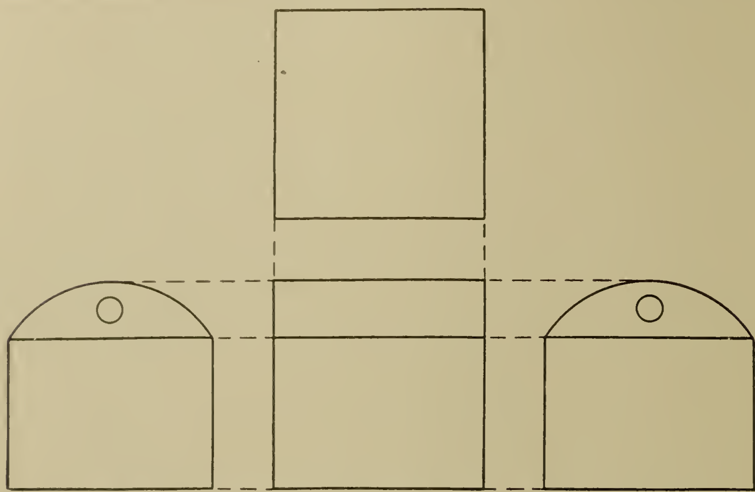

Fig. 100. Plan, Elevation, and End Views of a Box with a Curved Top

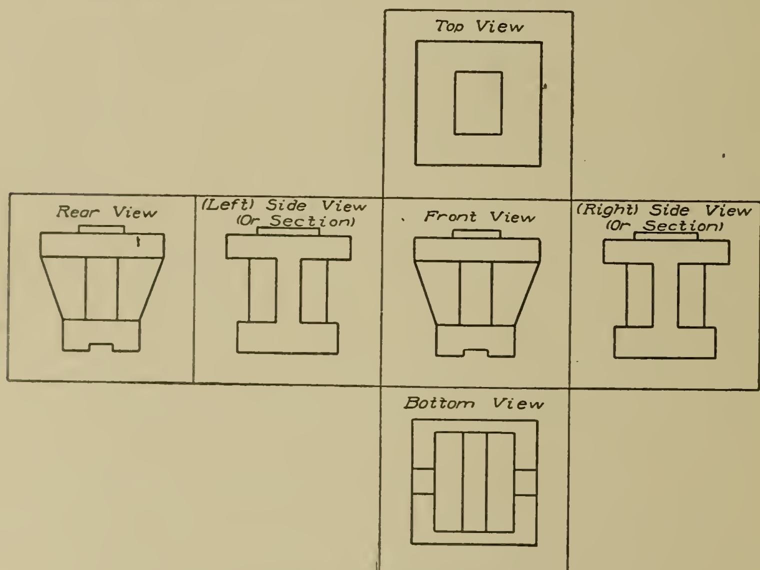

Fig. 101. Six Views of Object
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

front elevation and plan, by making several dots for the shape of the top, and drawing a curved line through these dots. The two

end views are placed as shown—the right-hand view at the right of the front view, and the left-hand view at the left. This gives the proper arrangement of the views as a draftsman would work them out on paper.

In Fig. 101 is represented a practical case where the object is sufficiently complicated to require a view of each of its six faces. As will be seen in the figure, six views are shown—front, top,

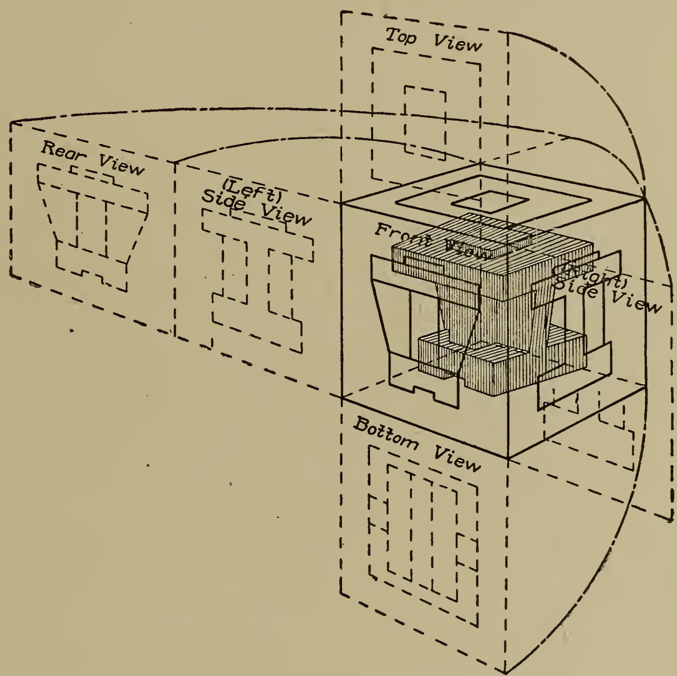

Fig. 102. Folding Out of the Projection Planes Into the Plane of the Surface of the Drawing Paper
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

bottom, right side, left side, and rear. In Fig. 102 is represented the method of folding out the projection planes after the faces of the object have been projected on them, in order to have them all in one plane—that of the surface of the drawing paper, as shown in Fig. 101.

Drawing the Projection on Paper. From the explanation just given, it will be seen that the projection views are all of the same size as the faces of the object they represent. They can, therefore,

be drawn just as readily on a sheet of drawing paper without the use of the ground glass. For the front view, measure the four front edges of the object, and lay off on the paper a figure of the same shape as the front of the object. Repeat the process for the top of the object, obtaining the top view, or plan; and for each end of the object, obtaining the end view, or side views. The bottom and rear views can be placed in the same way. Draw the plan view with its four corners directly over the four corners of the front view, and the bottom view with its four corners directly under. Draw the right end, or side, view with its four corners directly to the right of the four corners of the front elevation, and the left end, or left side, view and rear view, with their corners directly to the left of the corners of the front view.

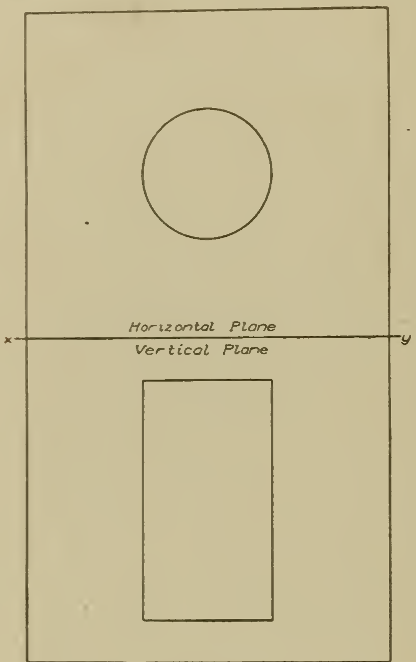

Fig. 103. Ground Line, xy, at Intersection of Horizontal and Vertical Planes

Projection Lines. As each projected point of an object shown in plan view must be directly over the projection of the same point in the front elevation, a vertical dotted line will connect these points, as projected in pairs; and as each projected point in an end view must be directly opposite the projection of the same point in the front elevation, a horizontal dotted line will connect these points, as projected in pairs. These dotted lines are called projection or construction lines.

Ground Line. Having the two planes, at right angles, on which the front elevation and plan are represented, when the top plane is turned up to bring the plan above the front elevation, as represented on the surface of the drawing paper, it revolves on the intersecting line of the two planes as an axis. This intersecting line xy

in Fig. 103, is called the ground line, and this is usually abbreviated to *GL*. The projections may be placed at any convenient distance above or below the *GL*, unless these distances are given in any problem. In beginning all ordinary projection work, it is customary to show the *GL* as a horizontal line between the front elevation and plan views, and the projection of any pair of points in the front and plan views are always in a line perpendicular to the *GL*. This is evident from the fact that the points in the plan view are directly

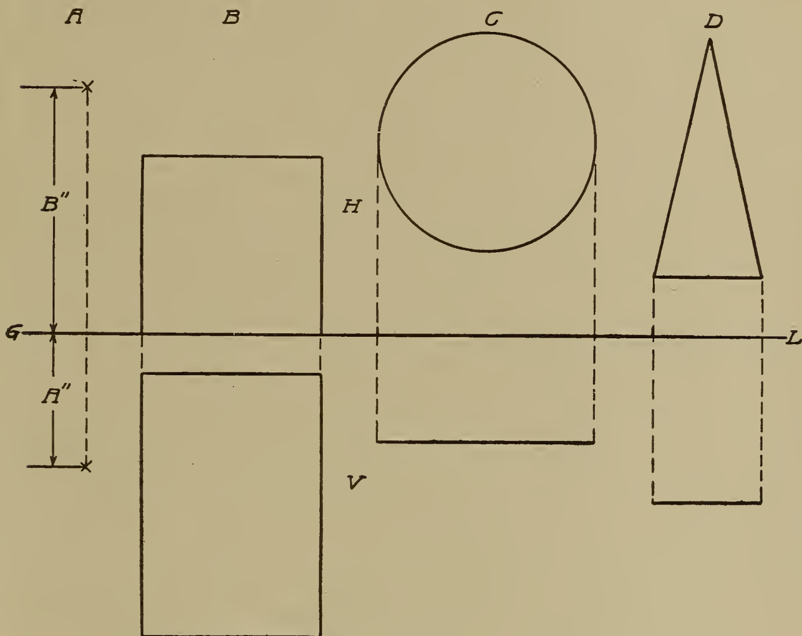

Fig. 104. Typical Projections

over the corresponding points in the front elevation. Although the ground line is usually used in learning the subject of projections, it is customary to omit it in practical work.

Rules of Projection. (1) *If a surface is perpendicular to either plane of projection, its projection on that plane is simply a line—a straight line if the surface is plane, a curved line if the surface is curved.*

(2) *The projected view of any point of any object on a plane is in a perpendicular drawn to the plane through the point of the object.*

(3) *If a straight line is perpendicular to a plane, its projection on that plane is a point; and if the straight line is parallel to the plane, the projection is a line equal in length to the line itself and makes the same angle with the ground line.*

(4) *All points on any object at the same height above its base must appear in the front elevation at the same distance below the ground line, and all points on an object at the same distance back of the front face must appear in the plan at the same distance above the ground line.*

Typical Examples of Projection. Figs. 104 and 105 show clearly several ideas of plan and elevation. In such work as this, it is

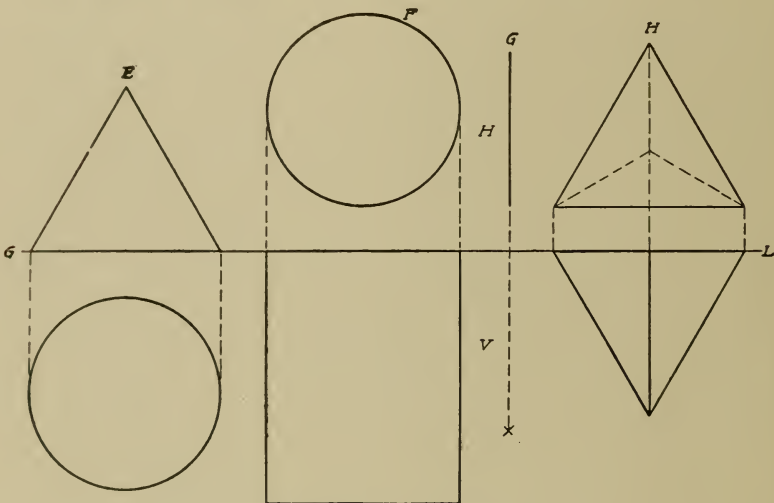

Fig. 105. Typical Projections

customary to call the vertical plane on which the front elevation is drawn *V*, and the horizontal plane on which the plan is drawn *H*.

A = a point *A''* below *H*, and *B''* in front of *V*

B = a square prism resting against *V*, two of its faces parallel to *H*

C = a circular disk in space parallel to *H*

D = a triangular card in space parallel to *H*

E = a cone with its base resting against *V*

F = a cylinder perpendicular to *H*, and with one end resting against *H*

G = a line perpendicular to V

H = a triangular pyramid back of V, with its base resting against H

PRACTICAL PROBLEMS IN PROJECTION

1. *Square Bar.* Fig. 106 represents a square bar. A is the front elevation, and shows the length and width of the bar, but not the thickness. There must then be another view. B is the plan,

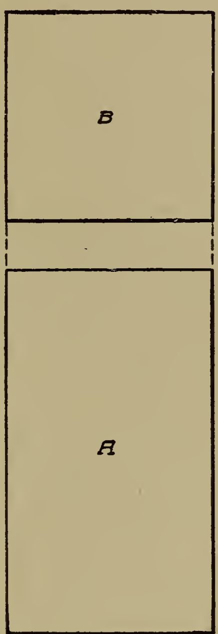

Fig. 106. Projections of Square Bar

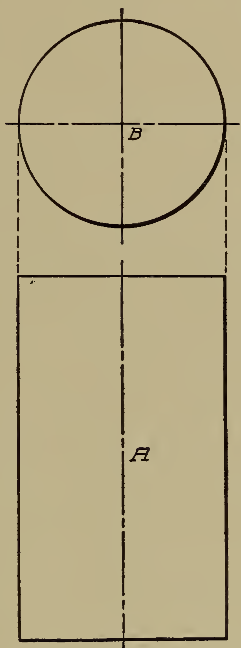

Fig. 107. Projections of Round Bar

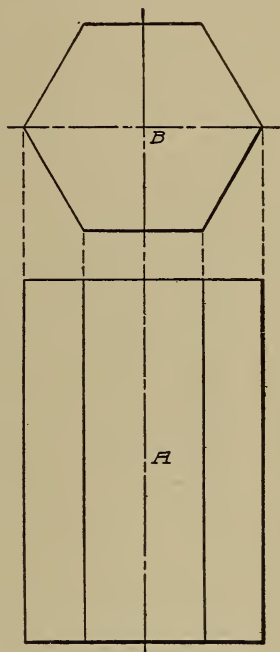

Fig. 108. Projections of Hexagonal Bar

and shows the width and thickness of the bar. From these two views the complete form of the bar is obtained and no other views are necessary when such is the case. In all working drawings, only as many views are shown as is necessary to determine the complete form of the object being drawn.

2. *Round Bar.* Fig. 107 represents a round bar. The front elevation A, shows the width and height of the bar, but does not show that it is round. The plan B, shows the circular top of the bar and of the proper diameter. In this problem, in addition to the

dotted projection lines connecting points in plan and elevation, it is advisable to put in dot and dash lines for center lines. Projection lines and center lines are construction lines, and may be erased when the drawing is finished, unless otherwise ordered.

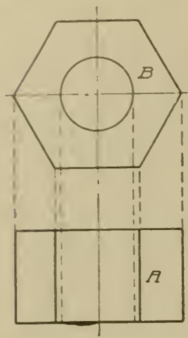

Fig. 109. Projections of Hexagonal Nut

3. *Hexagonal Bar.* Fig. 108 represents a hexagonal bar. In this case, center lines should be drawn. The front elevation *A*, shows the length of the bar, and the plan *B*, shows the form and the distance between faces. The vertical lines in the front elevation show the corners of the hexagonal form while both views show the distance from corner to corner of the hexagonal top.

4. *Hexagonal Nut.* Fig. 109 represents a hexagonal nut. Center lines should be drawn here also. The front elevation *A*, shows the thickness and width of the nut, and the cir-

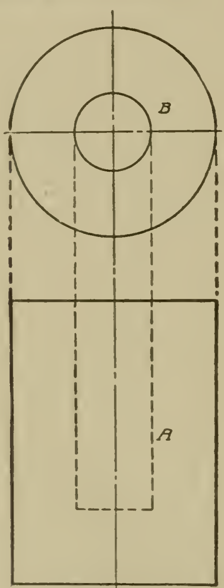

Fig. 110. Projections of Cylinder with Circular Hole

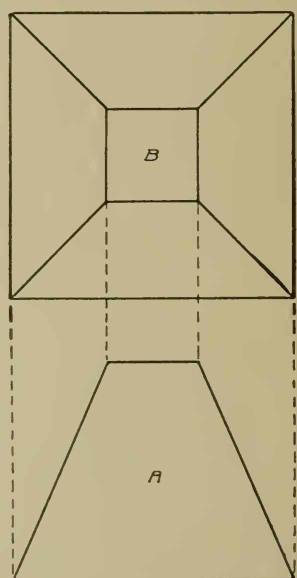

Fig. 111. Projections of Frustum of Square Pyramid

cular hole is shown by heavy dotted lines. Holes are always represented in this way. The plan *B*, shows the shape of the top of the nut, and also the shape of the hole.

5. *Cylinder with Circular Hole.* Fig. 110 represents a cylinder with a circular hole passing part way through. Center lines are needed here, and in fact where any circle, hexagon, octagon, or other shape except a square or rectangle occurs. The front elevation *A*, shows the height and width of the cylinder, and the depth and width of hole. The plan *B*, shows the top of the cylinder, its diameter, and the diameter of the hole.

6. *Frustum of Square Pyramid.* Fig. 111 represents a block in the form of a frustum of a square pyramid. The front elevation *A*, shows the height of the block, and the width of the top and bottom faces. The plan *B*, shows the width and depth of the top and bottom faces, and also the edges connecting these faces of the frustum.

7. *Square Bar with Cylindrical Portion.* Fig. 112 represents a square bar with a portion forged to a cylindrical form. The front elevation *A*, shows the length and width of the bar, and also the length and width of the cylindrical portion. The plan *B*, shows the square top, and by the dotted circle shows the shape of the cylindrical portion. The fact that this circle is dotted means that the cylindrical portion does not come clear through to the top. A bottom view *C*, is also shown here, as it gives a better idea of the complete form of the bar. Enough views should always be shown by the draftsman to give the workman a clear idea of what he is to make.

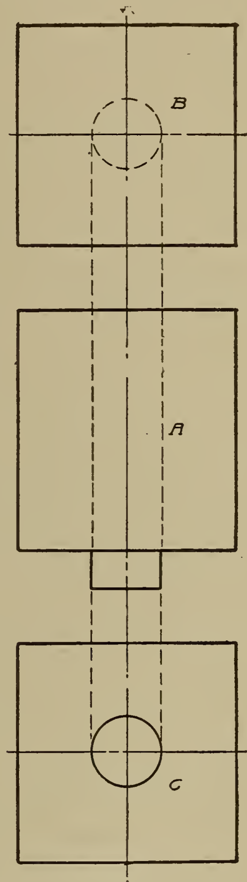

Fig. 112. Projections of Square Bar with Cylindrical Portion

8. *Circular Ring Made from Round Rod.* Fig. 113 represents a circular ring made from a round rod. The front elevation *A*, shows the thickness and the diameter of the ring, and the plan *B*, shows the circular form.

9. *Block with Number of Different Dimensions.* Fig. 114 represents a block with a number of different dimensions. The block

has been turned down in such a way that there are five different diameters, as shown. All these diameters, and the lengths between, may be shown in the front elevation *A*. From this view, only the forms of the cross-section could not be ascertained. Some might be square, some hexagonal, or some circular, but the plan *B* shows that all are circular.

Summary. The principles of projection which have been used so far, may be stated as follows:

(1) If a line is parallel to either the vertical or horizontal plane, its actual length is shown on that plane, and its other projection is parallel to the ground line.

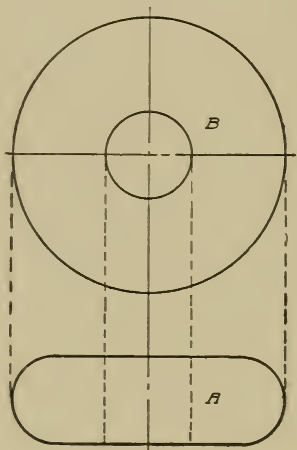

Fig. 113. Projections of Circular Ring

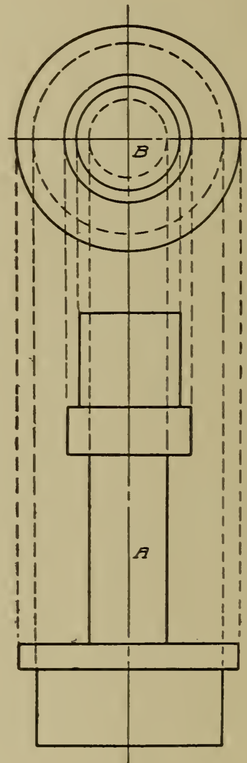

Fig. 114. Projections of Turned Block

(2) A line oblique to either plane has its projections on that plane shorter than the line itself, and its other projection oblique to the ground line.

(3) No projection can be longer than the line itself.

(4) If two lines intersect, their projections must cross, and the point of crossing in the front elevation must be directly under the point of crossing in the plan.

(5) A plane surface, if parallel to either plane, is shown on that plane in its true size and shape; if oblique, it is shown smaller than the true size, and if perpendicular it is shown as a straight line.

(6) Lines parallel in space have both their vertical and horizontal projections parallel.

TRUE LENGTH OF LINES

Principles. If a line is parallel to a plane, its projection on that plane will be equal in length to the line itself, as represented in Fig. 115. If a line is perpendicular to a plane, its projection on

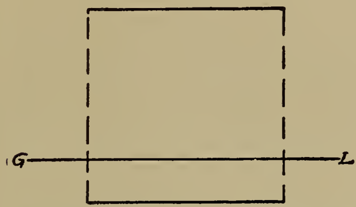

Fig. 115. Projections of a Line Parallel to Plane

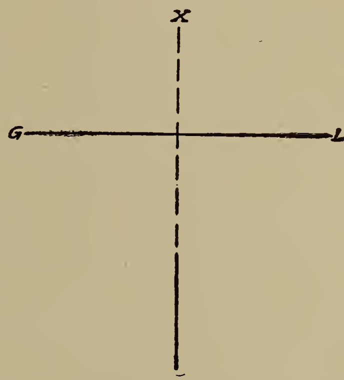

Fig. 116. Projections of a Line Perpendicular to Plane

the plane will be a point, as represented by the cross in Fig. 116. If a line is inclined to a plane, its projection on that plane will be shorter than the line itself, as represented in Fig. 117. If a line is parallel to the horizontal or vertical plane, its projection on the other plane will be parallel to the ground line, as represented in Fig. 118. A line inclined to both the horizontal

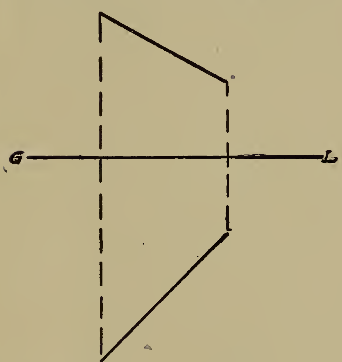

Fig. 117. Projections of a Line Inclined to Plane

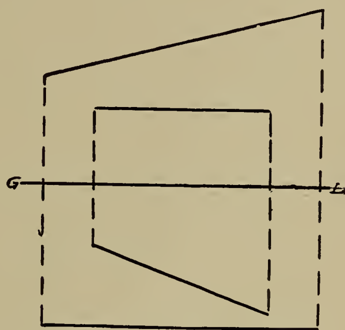

Fig. 118. Projections of Lines Parallel to Ground Line

and vertical planes will not show its true length in either projection, as represented in Fig. 119. In a case like the one last mentioned, the true length of the line is found by revolving the line until it is parallel to one of the planes. Then, its projection on that plane will be its true length.

True Length by Revolving Horizontal Projection. In Fig. 120 is shown the horizontal and vertical projections of the line AB, and to find the true length of the line itself proceed as follows: Swing the horizontal projection $A^h B^h$ about one end A^h as a pivot, until it is parallel to the ground line. Project the new point $B_1{}^h$ downward to a point on the vertical plane to a line drawn from B^v parallel to the ground line, locating the point $B_1{}^v$. The line connecting $B_1{}^v$ and A^v is the true length desired, since the true length of a line is always shown by its projection on a plane when the line is parallel to that plane.

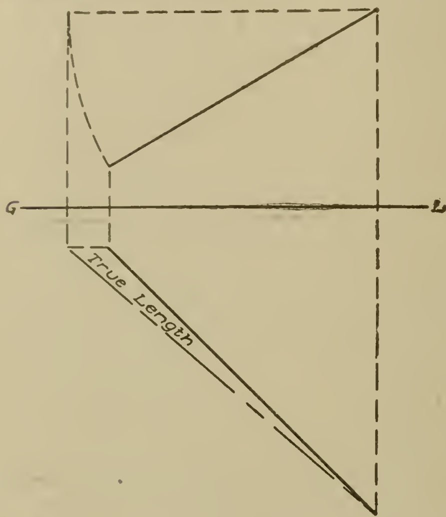

Fig. 119. True Length of Inclined Line not Shown in Its Projections

True Length by Revolving Vertical Projection. In Fig. 121 is shown the method of finding the true length of the same line as

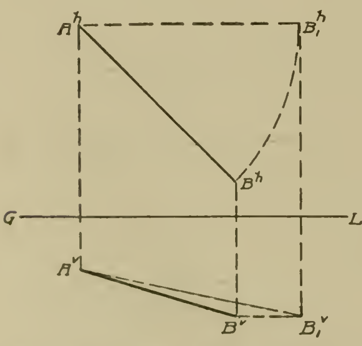

Fig. 120. True Length of a Line by Revolving Horizontal Projection

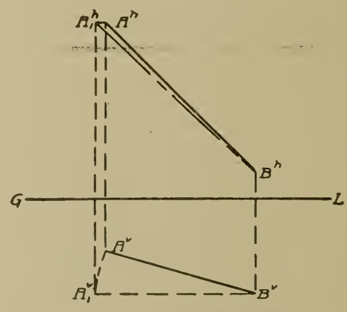

Fig. 121. True Length of a Line by Revolving Vertical Projection

in Fig. 120, but by revolving the vertical projection. The method is the same. Revolve $A^v B^v$ about the end B^v as a pivot until it is parallel to the ground line, and then project $A_1{}^v$ up to $A_1{}^h$ on the

horizontal plane at the same distance from the ground line as A^h. The true length is then shown on the horizontal plane by the line connecting $A_1{}^h$ and B^h. Projection lines representing the true length are always shown as dot and dash lines, as in Fig. 120 and 121.

REPRESENTATION OF OBJECTS

Rectangular Prism or Block. In Fig. 122 there is represented a rectangular prism or block, whose length is twice its width. The elevation shows its height. As the block is placed at an angle, three of the vertical edges will be visible, and the fourth, invisible. In mechanical drawing, the edges, which in projection form a part of the outline or contour of the figure, must always be visible, hence are always drawn as full lines, while the lines or edges which are invisible are drawn dotted. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 122, the plan shows that the dotted edge AB is the back edge, and in Fig. 123, the elevation shows that the dotted edge CD is the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan, if an edge projected within the outline is a lower edge, it is dotted.

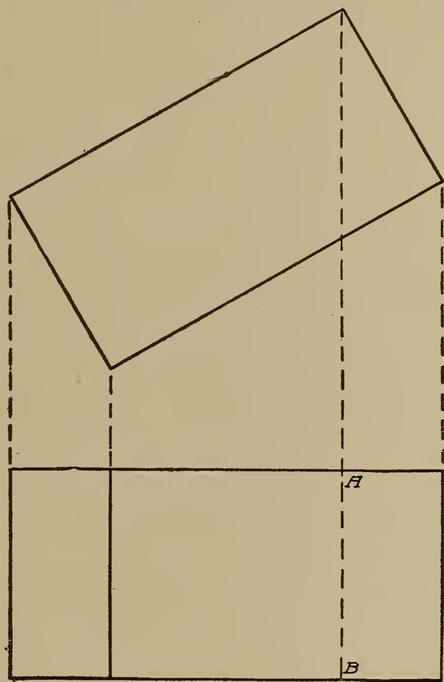

Fig. 122. Projections of a Rectangular Prism or Block

Triangular Prism or Block. The end view shown in Fig. 123 is obtained by projecting the points of the plan across to a plane at right angles to the horizontal and vertical planes, then revolving them down through 90 degrees and continuing the projections to meet the projection lines drawn across from

the elevation. Connecting the points thus obtained gives the end view. End or side views of any object are obtained by projection in this way.

Triangular Block with Square Hole. The plan, elevation, and end views of a triangular block with a square hole from end to end are shown in Fig. 124. In this case the plan and elevation alone would not be sufficient to positively determine the shape of the hole, but the end view shows at a glance that it is square.

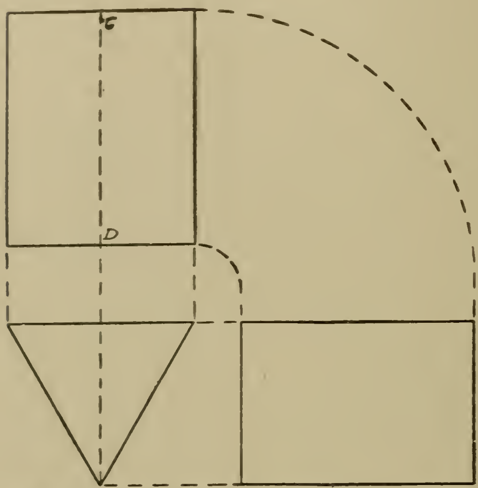

Fig. 123. Projections of a Triangular Prism or Block

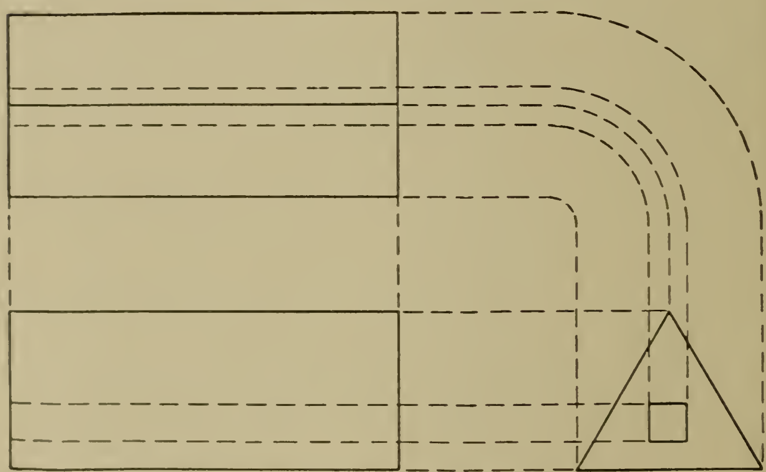

Fig. 124. Projections of a Triangular Block with Square Hole

ROTATING AND INCLINING OF OBJECTS

Method of Rotating Object. The natural way to place an object to be shown by projections would be in the simplest position; that is, with an edge or face parallel to either the horizontal or

vertical plane of projection. Sometimes it is necessary, however, to draw the views of an object in a position at an angle to the planes. In such case it is usually advisable to draw the object parallel to one of the planes, and then rotate it to the required position about an axis perpendicular to a plane of projection.

When an object is rotated in this way, about an axis perpendicular to a plane, its projection on that plane will remain unchanged

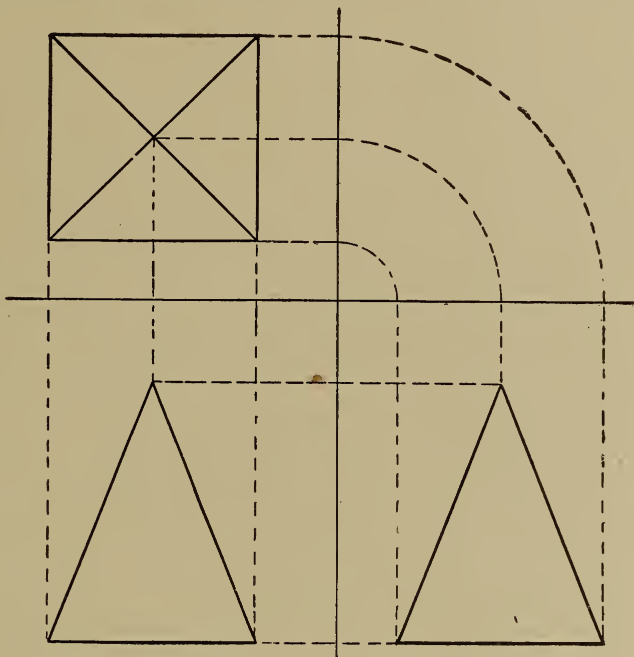

Fig. 125. Plan, Front, and Side Views of a Square Pyramid

in size and shape, and the dimensions parallel to this axis on the other planes will remain the same.

Pyramid. In Fig. 125, the plan, front, and side views of a pyramid are shown, and in Fig. 126 is shown the same pyramid after it has been rotated through 30 degrees about an axis perpendicular to the horizontal plane. The height of the pyramid has not been altered by this rotation and, therefore, the front and side views are the same height as in the original front view.

Now, if the pyramid in Fig. 125 is rotated about an axis perpendicular to the vertical plane, the front view will not be altered,

and may be copied in the new position at an angle of 30 degrees, as shown in Fig. 127. The distances above the ground line to any points in the top view are not altered, and the distances of the various points can be taken on the lines projected up from the points of the front view with a pair of dividers, or the points can be obtained by projecting across from the original top view to meet the projection lines drawn up from the front view. The side view dimensions are not altered, and this view can therefore be obtained in

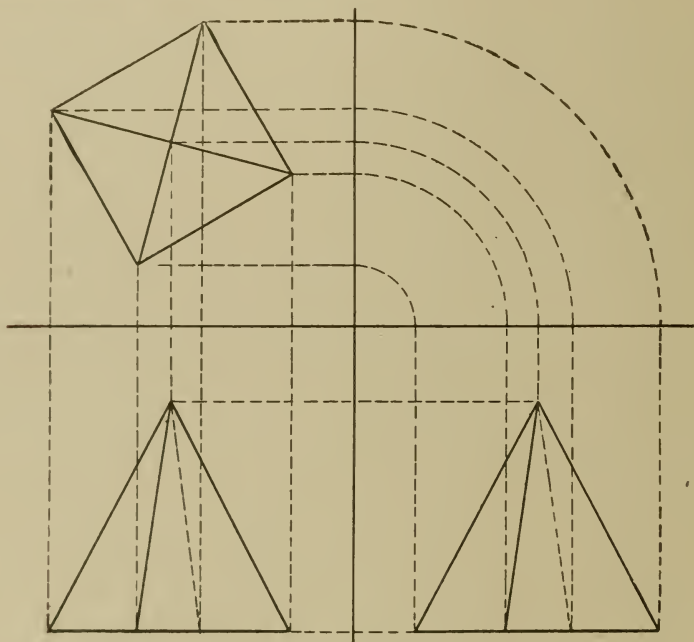

Fig. 126. Plan, Front and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Vertical Plane

the usual way, by projecting across from the front view, and revolving down from the plane at right angles to the horizontal and vertical planes the points projected across from the top view.

Cylinder in Inclined Position to Horizontal Plane. As shown in Fig. 128, first draw the plan, a circle, at A. Then draw the rectangle at B, representing the front view. Now, draw the rectangle at C, representing the front view at the desired angle. This rectangle C is the same size as the view at B, since the cylinder

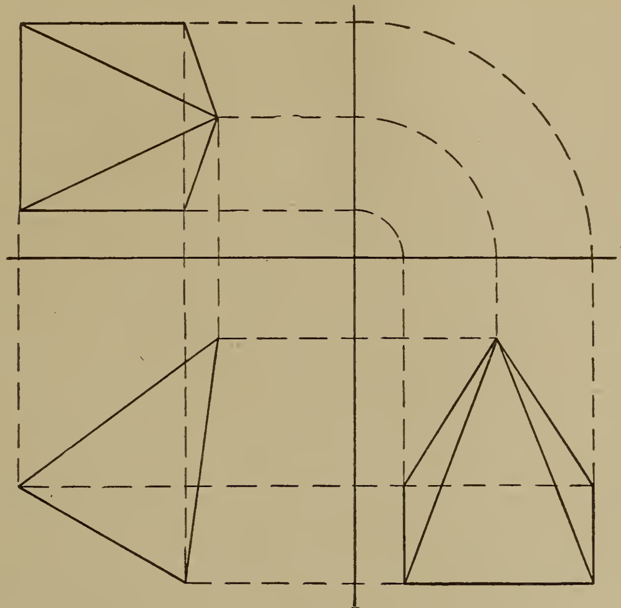

Fig. 127. Plan, Front, and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Horizontal Plane

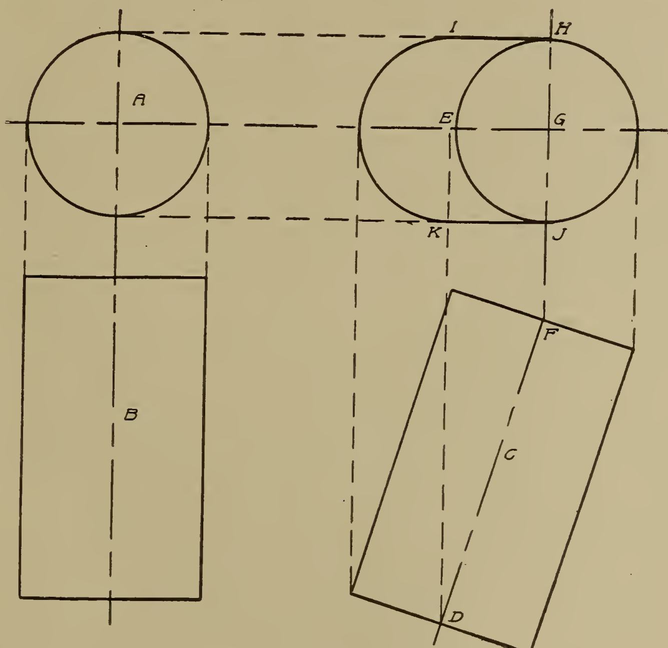

Fig. 128. Projections of Cylinder Inclined to Horizontal Plane

has simply been inclined to the horizontal plane, but kept parallel to the vertical plane. The point *D*, the center of the circle forming the base of the cylinder, is projected up to the point *E*, and with this point as a center, a circle representing the plan view of the base is drawn. Then from *F* project up to *G*, and with this point as a center draw the circle representing the plan view of the top of the

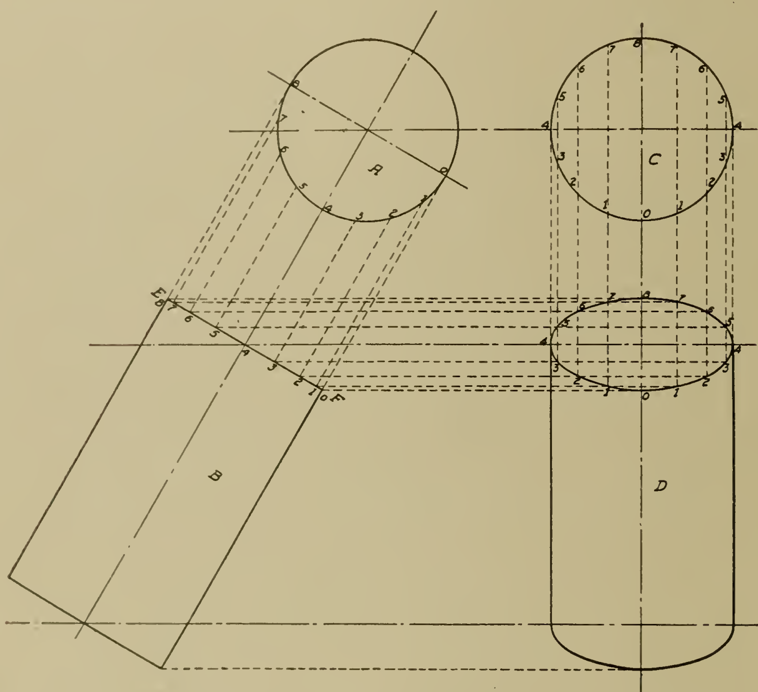

Fig. 129. Method of Finding the Projection, in the Form of an Ellipse, of the Top of a Cylinder Greatly Inclined to a Plane

cylinder. Connecting these two circles with horizontal lines *HI* and *JK*, representing the sides of the cylinder, completes the plan view, and the problem is finished.

As the cylinder is at an angle with the horizontal plane, it will be seen that the top and bottom of the cylinder in the plan view are not circles, but ellipses. It is, however, customary to draw them with the compass, as circles, when the angle of the cylinder with the plane is not great.

Cylinder Greatly Inclined to Horizontal Plane. In Fig. 129 the plan and front elevation of the top of the cylinder are drawn at the desired angle with the horizontal plane at A and B, respectively. The plan view at A is then transferred to C. In each of these plan views divide the lower semicircle into a number of equal parts, eight in this case. From the view of A, project the points 0—8, parallel to the center line, down to EF, and then project across to the projection lines drawn vertically down from the points 0—8 in C. The points of intersection of projection lines, correspondingly numbered, form the shape of the ellipse representing the top of the side view of the inclined cylinder D, and the ellipse drawn through these points completes this view. The side lines of the cylinder may now be drawn, and the curve representing the bottom of the side view may easily be copied from the lower half of the ellipse representing the top view. When the points have been located, the ellipses may be drawn through them with the aid of an irregular curve.

ILLUSTRATIVE EXAMPLES

1. *Construct plan and elevation of a regular hexagonal pyramid.* It is evident that two distinct geometrical views are necessary to convey a complete idea of the form of the object; an elevation to represent the sides of the body, and to express its height; and a plan of the upper surface to express the form horizontally.

It is to be observed that this body has an imaginary axis or center line, about which the same parts or segments of the body are equally distant; this is an essential characteristic of all symmetrical figures.

Draw a horizontal dotted line MN for the center line of the plan views, Fig. 130. Then draw a perpendicular ZZ' to MN.

In delineating the pyramid, it is necessary, in the first place, to construct the plan. The point S', where the line ZZ' intersects the line MN, is to be taken as the center of the figure, and from this point, with a radius equal to the side of the hexagon which forms the base of the pyramid, describe a circle, cutting MN in A' and D'. From these points, with the same radius, draw four arcs of circles, cutting the primary circle in four points. These six points being joined by straight lines, will form the figure $A' B' C' D' E' F'$,

which is the base of the pyramid; and the lines $A'D'$, $B'E'$, and $C'F'$, will represent the projections of its edges foreshortened as they would appear in the plan. If this operation has been correctly performed, the opposite sides of the hexagon should be parallel to each other and to one of the diagonals; this should be tested by the application of the square or other instrument proper for the purpose.

By the help of the plan obtained as above described, the vertical

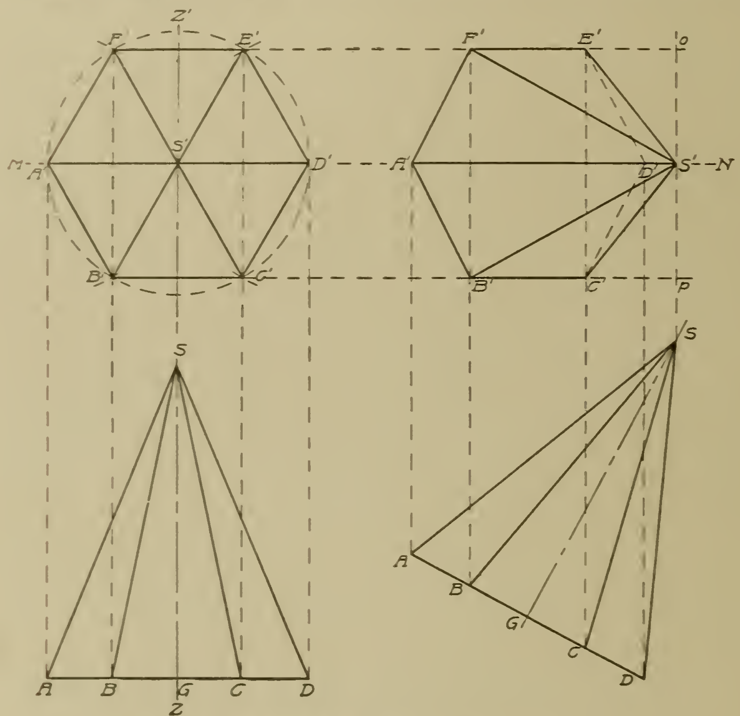

Fig. 130. Construction of Regular Hexagonal Pyramid

projection of the pyramid may be easily constructed. Since it is directly under the plan, it must be projected vertically downward; therefore, from each of points A', B', C', D', drop perpendiculars to AD, the base line of the pyramid in the elevation. The points of intersection, A, B, C, and D, are the true positions of all the angles of the base; and it only remains to determine the height of the pyramid, which is to be set off from the point G to S, and to

draw SA, SB, SC, and SD, which are the only edges of the pyramid visible in the elevation. Of these it is to be remarked that SA and SD alone, being parallel to the vertical plane, are seen in their true length; and, moreover, that from the assumed position of the solid under examination, the points F' and E' being situated in the lines BB' and CC', the lines SB and SC are each the projections of two edges of the pyramid.

2. *Construct the projections of the pyramid, Example 1, having its base set in an inclined position, but with its edges SA and SD still parallel to the vertical plane,* Fig. 130.

It is evident, that with the exception of the inclination, the vertical projection of this solid is precisely the same as in the preceding example, and it is only necessary to show the same view of the pyramid in its new position. For this purpose, after having fixed the position of the point D, draw through this point a straight line DA, making with MN an angle equal to the desired inclination of the base of the pyramid. Then set off the distance DA, equal to that used in Example 1; erect a perpendicular on the center, and set off GS equal to the height of the pyramid. Transfer also from the first example the distance BG and CG to the corresponding points, and complete the figure by drawing the straight lines AS, BS, CS, and DS.

In constructing the plan of the pyramid in this position, it is to be remarked that since the edges SA and SD are still parallel to the vertical plane, and the point D remains unaltered, the projection of the points A, D, and S, will still be in the line MN. The position of A' is determined by the intersection of the perpendicular AA' with MN. The remaining points, B', C', etc., in the projection of the base, are found, in a similar manner, by the intersections raised from the corresponding points in the elevation, with lines drawn parallel to MN, at a distance (set off at o, p) equal to the width of the base. By joining all the contiguous points, the figure $A'B'C'D'E'F'$ is obtained representing the horizontal projection of the base, two of its sides, however, being dotted, as they must be supposed to be concealed by the body of the pyramid. The vertex S having been similarly projected to S', and joined by straight lines to the several angles of the base, the projection of the solid is completed.

INTERSECTIONS

If one surface meets another at some angle, an **intersection** is produced. Either surface may be plane, or curved. If both are plane, the intersection is a straight line; if one is curved, the intersection is a curve, except in a few special cases; and if both are curved, the intersection is usually curved. In the latter case, the

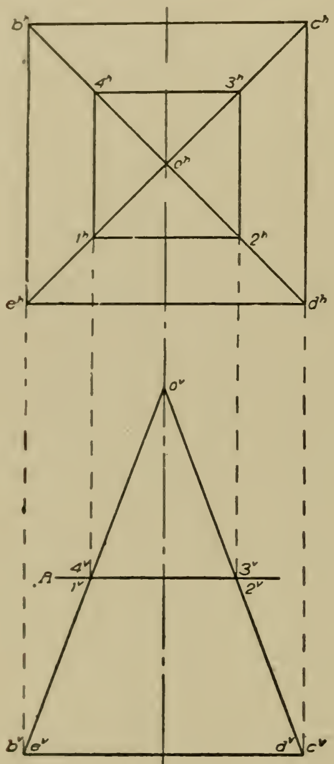

Fig. 131. Intersection of Plane and Square Pyramid

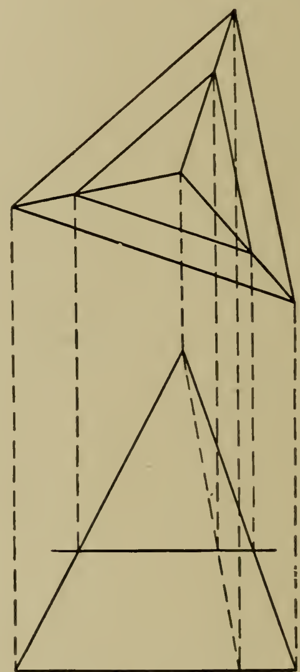

Fig. 132. Intersection of Plane and Triangular Pyramid

entire curve does not always lie in the same planes. If all points of any curve lie in the same plane, it is called a *plane curve*. A plane intersecting a curved surface must always give either a plane curve or a straight line.

Planes with Planes. In Fig. 131 a square pyramid is cut by a plane *A* parallel to the horizontal. This plane cuts from the pyra-

mid a four-sided figure, the four corners of which will be the points where A cuts the four slanting edges of the solid. The plane intersects edge ob at point 4^v in elevation. This point must be found in plan vertically above on the horizontal projection of line ob, that is, at point 4^h. Edge oe is directly in front of ob, so is shown in elevation as the same line, and plane A intersects oe at point 1^v in

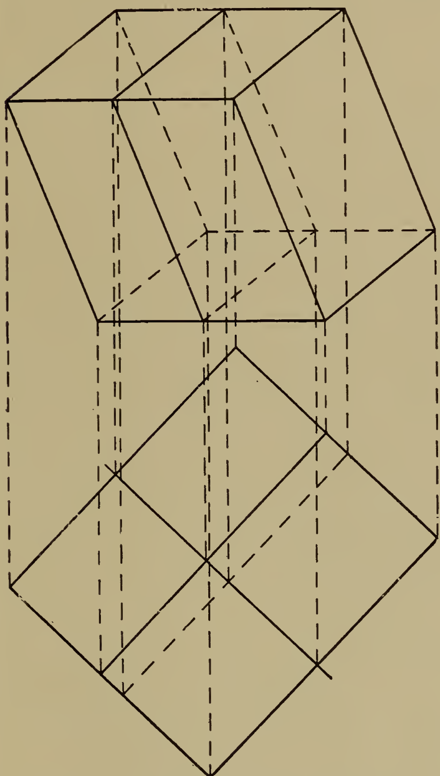

Fig. 133. Intersection of Plane and Prism

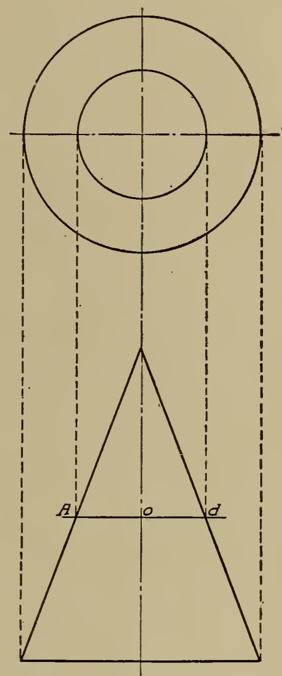

Fig. 134. Intersection of Plane and Cone

elevation, found in plan at 1^h. Points 3 and 2 are obtained in the same way. The intersection is shown in plan as the square 1-2-3-4, which is also its true size as it is parallel to the horizontal plane. In a similar way the intersections are found in Figs. 132 and 133. It will be seen that in these three cases where the planes are parallel to the bases, the sections are of the same shape as the bases, and have their sides parallel to the edges of the bases.

It is an invariable rule that when such a solid is cut by a plane parallel to its base, the section is a figure of the same shape as the base. If then in Fig. 134 a right cone is intersected by a plane parallel to the base the section must be a circle, the center of which in plan coincides with the apex. The radius must equal *od.*

In Fig. 135 and Fig. 136 the cutting plane is not parallel to the base, hence the section will not be of the same shape as the base.

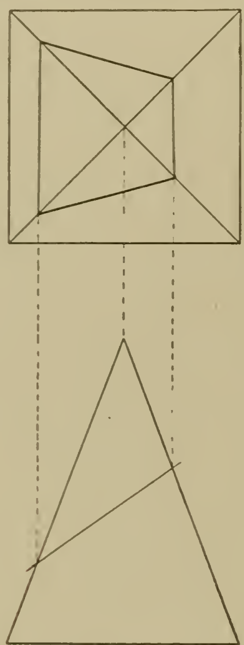

Fig. 135. Intersection of Plane and Square Pyramid

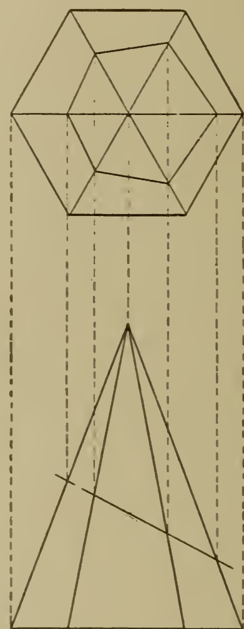

Fig. 136. Intersection of Plane and Hexagonal Pyramid

The intersections are found, however, in exactly the same manner as in the previous figures, by projecting the points where the plane intersects the edges in elevation, on to the other view of the same line.

ILLUSTRATIVE EXAMPLES

1. Find the horizontal projection of a transverse section of the pyramid of Fig. 130, made by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let all the sides of the base be at an angle with $M N$, Fig. 137.

Having drawn the vertical SS', the center line of the figures, its point of intersection with the line MN is the center of the plan. Since none of the sides of the base are to be parallel with MN, draw a diameter $A'D'$ making the required angle with MN, and from the points A' and D' proceed to set out the angular points of the hexagon, as in Fig. 130. Then join the angular points which are diametrically opposite and project the figure thus obtained upon the vertical plane, as shown.

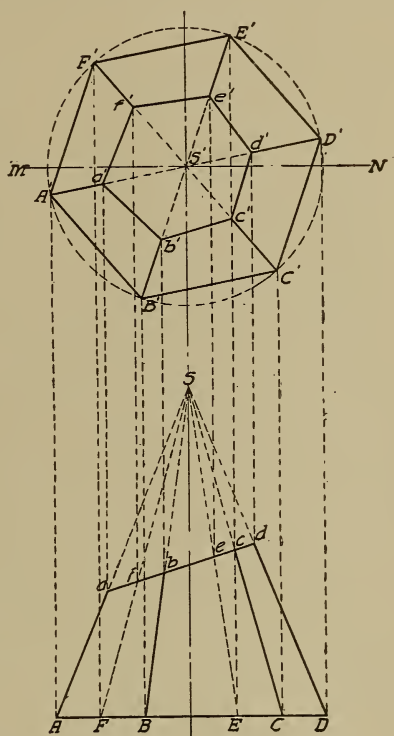

Fig. 137. Frustum of Hexagonal Pyramid

Now, if the cutting plane be represented by the line ad in the elevation, it is obvious that it will expose, as the section of the pyramid, a polygon whose angular points being the intersections of the various edges with the cutting plane, will be projected in perpendiculars drawn from the points where it meets these edges respectively. From the points a, f, b, etc., raise the perpendiculars aa', ff', bb', etc., to meet the lines $A'D'$, $F'C'$, $B'E'$, etc. When the contiguous points of intersection of these lines are joined, a six-sided figure will be formed which will represent the section required. The edges FS and ES being concealed in the elevation, but necessary for the construction of the plan, have been expressed in dotted lines, as is also the portion of the pyramid situated above the cutting plane which, though supposed to be removed, is necessary in order to draw the lines representing the edges.

2. Find the horizontal projection of the transverse section of a regular five-sided pyramid, cut by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let one edge of the pyramid, BS, be in a plane

perpendicular to both the horizontal and the vertical planes of projection, as shown in Fig. 138.

The plan of the pyramid is constructed by describing from the center S' a circle circumscribing the base, and from B' dividing the circumference into five equal parts, and joining the contiguous points of division by straight lines. These form the polygon $A' B' C' D' E'$, whose angles, when joined to the center S', show the projections of the edges of the pyramid. Then, following the method above explained, the elevation and the horizontal projection of the section made by the plane $a c$ are obtained. But that method will not suffice for the determination of the point b', because the perpendicular let fall from the corresponding point b, in the elevation, coincides with the projection of the edge $B S$. Let the pyramid supposedly be turned a quarter of a revolution round its axis; the line $B' S'$ will then have assumed the position $S' b^2$. Project the point b^2 to b^3, and join $S b^3$. Then since the required point must also be conceived to have described a quarter of a circle in a plane parallel to the horizontal plane, and that its new position

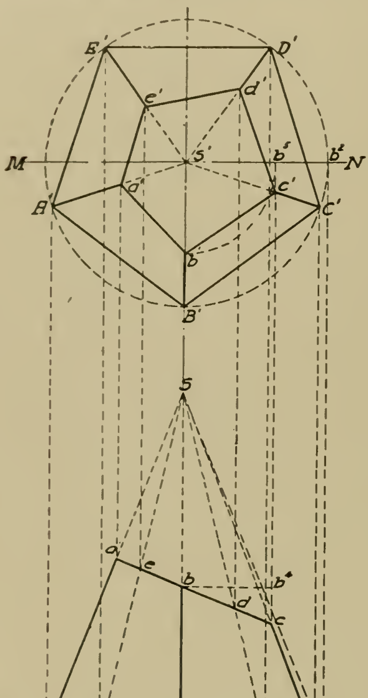

Fig. 138. Frustum of Pentagonal Pyramid

must be in the line $S b^3$, it is obvious that its vertical projection is the point b^4, the intersection of a horizontal line drawn through b with the line $S b^3$. The distance $b b^4$ may then be used to determine the distance from S' to b', and determines the position of the latter point in the plan; or, following a more methodical process, by projecting the point b^4 to b^5, and describing a circle from the center S' passing through b^5, its intersection with $B'S'$ is the point sought.

Planes with Cones or Cylinders. Sections cut by a plane from a cone have already been defined as *conic sections*. These sections may be any of the following: two straight lines, circle, ellipse, parabola, hyperbola. All except the parabola and hyperbola may also be cut from a cylinder.

Methods have previously been given for constructing the ellipse, parabola, and hyperbola, without projections; it will now be shown that they may be obtained as actual intersections.

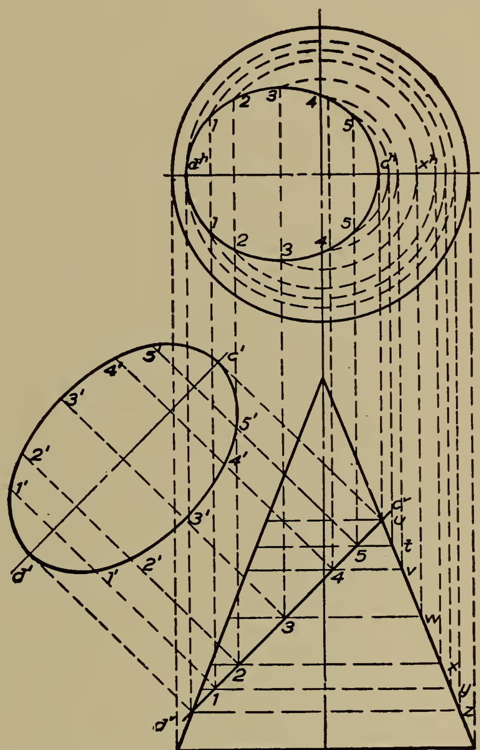

Fig. 139. Ellipse—Section from a Cone

Ellipse. In Fig. 139 the plane cuts the cone obliquely. To find points on the curve in plan take a series of horizontal planes xyz, etc., between points c^v and d^v. One of these planes, as w, should be taken through the center of cd. The points c and d must be points on the curve, since the plane cuts the two contour elements at these points. Contour elements are those forming the outline. The horizontal projections of the contour elements will be found in a horizontal line passing through the center of the base; hence the horizontal projection of c and d will be found on this center line, and will be the extreme ends of the curve.

The plane x cuts the surface of the cone in a circle, as it is parallel to the base, and the diameter of the circle is the distance between the points where x crosses the two contour elements. This circle, lettered x on the plan, has its center at the horizontal projection of the apex. The circle x and the curve cut by the plane are both on

the surface of the cone, and their vertical projections intersect at the points 2-2. Point 2 on the elevation then represents two points which are shown in plan directly above on the circle x, and are points on the required intersection. Planes y and z, and as many more as may be necessary to determine the curve accurately, are used in the same way. The curve found is an ellipse. The student will readily see that the true size of this ellipse is not shown in the plan, for the plane containing the curve is not parallel to the horizontal.

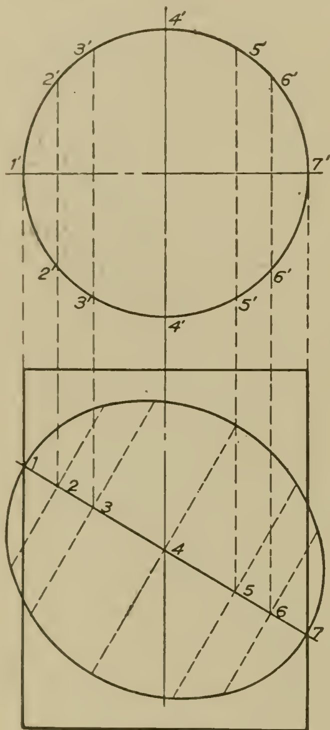

Fig. 140. Ellipse—Section from a Cylinder

In order to find the *actual size of the ellipse,* it is necessary to place its plane in a position parallel either to the vertical or to the horizontal. The actual length of the long diameter of the ellipse must be shown in elevation, $c^v d^v$, because the line is parallel to the vertical plane. The plane of the ellipse then may be revolved about $c^v d^v$ as an axis until it becomes parallel to V, when its true size will be shown. For the sake of clearness of construction, $c^v d^v$ is imagined moved over to the position $c' d'$, parallel to $c^v d^v$. The lines 1-1, 2-2, 3-3 on the plan show the true width of the ellipse, as these lines are parallel to H, but are projected closer together than their actual distances. In elevation these lines are shown as the points 1, 2, 3, at their true distance apart. Hence if the ellipse is revolved around its axis $c^v d^v$, the distances 1-1, 2-2, 3-3 may be laid off on lines perpendicular to $c^v d^v$, and the true size of the figure be shown.

In Fig. 140 a plane cuts a cylinder obliquely. This is a simpler case, as the horizontal projection of the curve coincides with the base of the cylinder. To obtain the true size of the section, which is an ellipse, any number of points are assumed on the plan and

projected down on the cutting plane, at 1, 2, 3, etc. The lines drawn through these points perpendicular to 1′-7′ are made equal in length to the corresponding distances 2′-2′, 3′-3′, etc., on the plan, because 2′-2′ is the true width of curve at 2.

Parabola. If a cone is intersected by a plane which is parallel to only one of the elements, as in Fig. 141, the resulting curve is

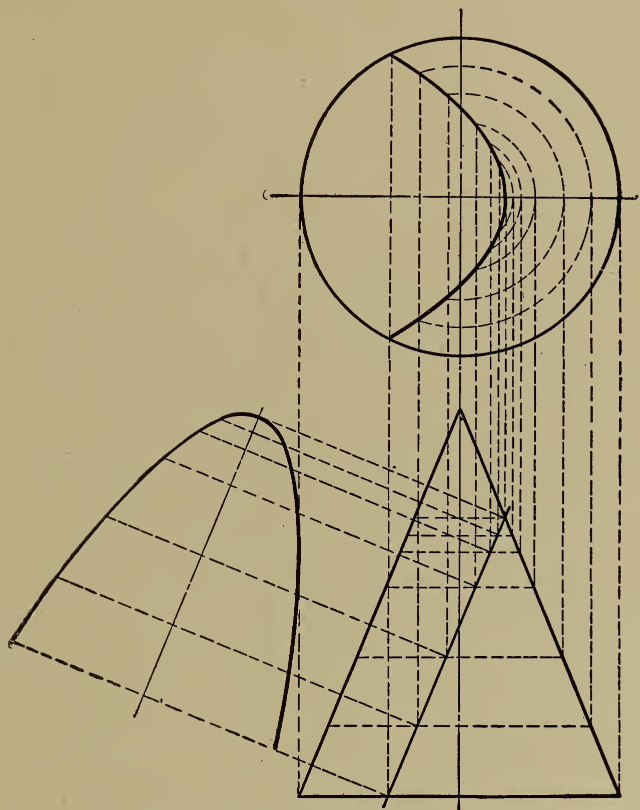

Fig. 141. Parabola—Section from a Cone

the *parabola,* the construction of which is exactly similar to that for the ellipse, as given in Fig. 139. If the intersecting plane is parallel to more than one element, or is parallel to the axis of the cone, a hyperbola is produced.

In Fig. 142, the vertical plane *A* is parallel to the axis of the cone. In this instance the curve when found will appear in its true

size, as plane A is parallel to the vertical. Observe that the highest point of the curve is found by drawing the circle X on the plan tangent to the given plane. One of the points where this circle crosses the diameter is projected down to the contour element of the cone, and the horizontal plane X drawn. Intermediate planes Y, Z, etc., are chosen, and corresponding circles drawn in plan. The points where these circles are crossed by the plane A are points on the curve, and these points are projected down to the elevation on the planes Y, Z, etc.

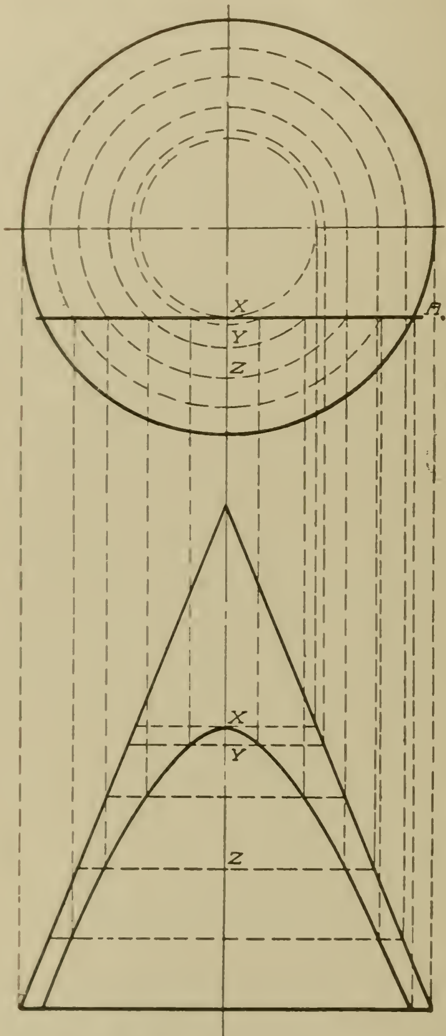

Fig. 142. Hyperbola—Section from a Cone

DEVELOPMENT OF SURFACES

General Details of Process. A surface may be considered as formed by the motion of a line. Any length of line moved sidewise in any direction will form a surface, of a width equal to the length of the line, and of a length equal to the distance over which the line is moved. There are two different classes of surfaces; namely, those formed by a moving straight line, and those formed by a moving curved line.

In some construction work, patterns of different faces or of the whole surface must be made; in stone cutting, for example,

there must be a pattern giving the shape of any irregular surface, and in sheet-metal work a pattern must be made such that, when a sheet is cut, it can be so formed that it will be of the same shape as the original object.

This pattern making, or the laying out of a complete surface on one plane, is called the development of the surface. Any surface

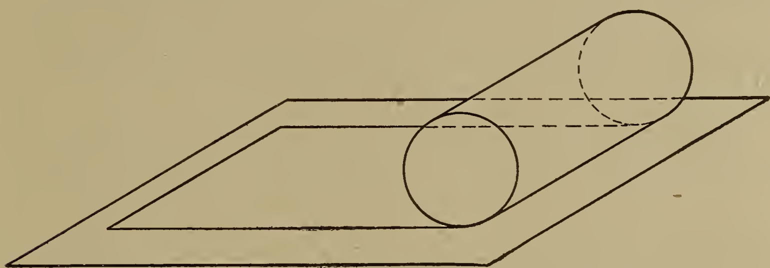

Fig. 143. Development of a Right Cylinder Rolled Out on a Plane

which can be smoothly wrapped about by a sheet of paper, can be developed. Figures made up of planes and single curved surfaces only would be of this nature. Double curved surfaces and warped surfaces cannot be developed, and patterns of such surfaces, when desired, must be made by an approximate method which requires two or more pieces to make the complete pattern.

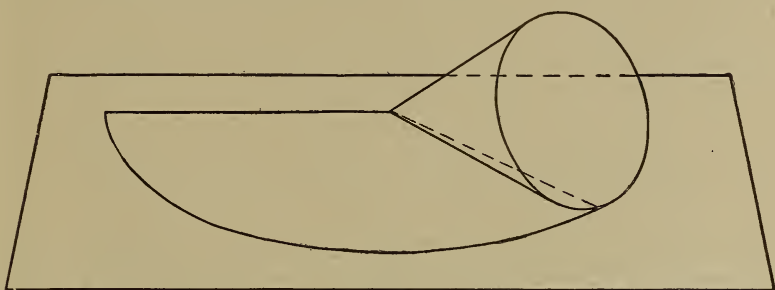

Fig. 144. Development of a Right Cone Rolled Out on a Plane

By finding the true size of all the faces of an object made up of planes, and joining them in order at their common edges, the developed surface will be formed. The best way to do this is to find the true length of the edges of the object.

Right Cylinder. In Fig. 143 is represented a right cylinder rolling on a plane. The development is formed by one complete

revolution of the cylinder and is a rectangle, the width being equal to the height of the cylinder and the length to the circumference.

Right Cone. In Fig. 144 is represented a right cone rolling out its development, which is a sector of a circle. The arc equals the circumference of the circle forming the base of the cone, and the radius equals the slant height.

The projections of any object must be drawn before the development can be made, but it is necessary only to draw such views as are required for finding the lengths of elements, and true sizes of cut surfaces.

Rectangular Prism. In order to find the development of the rectangular prism in Fig. 145, the back face, 1-2-7-6, is supposed

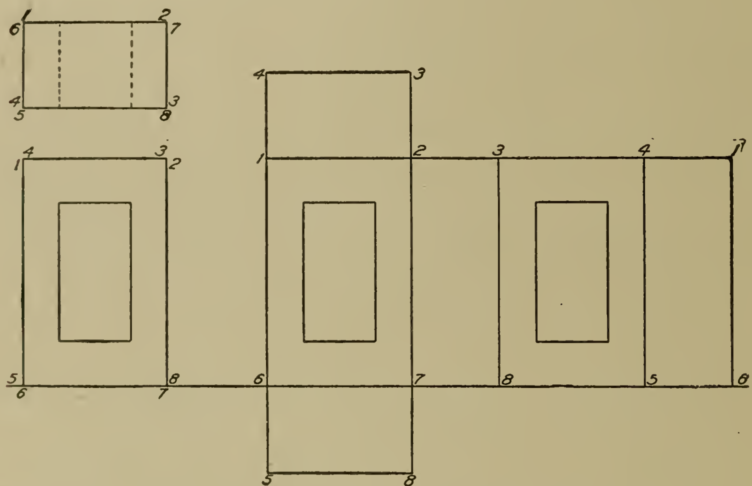

Fig. 145. Development of Hollow Rectangular Prism

to be placed in contact with some plane, then the prism turned on the edge 2-7 until the side 2-3-8-7 is in contact with the same plane, and this process continued until all four faces have been placed on the same plane. The rectangles 1-2-3-4 and 6-7-8-5 are for the top and bottom, respectively. The development then is the exact size and shape of a covering for the prism. If a rectangular hole is cut through the prism, the openings in the front and back faces will be shown in the development in the centers of the two broad faces.

The development of a right prism, then, consists of as many rectangles joined together as the prism has sides, these rectangles being the exact size of the faces of the prism, and in addition two polygons the exact size of the bases. It will be found helpful in developing a solid to number or letter all of the corners on the projections, then designate each face when developed in the same way as in the figure.

Cone. If a cone be placed on its side on a plane surface, one element will rest on the surface. If now the cone be rolled on the

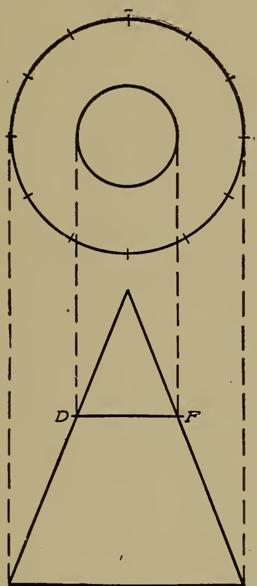

Fig. 146. Plan and Elevation of Cone

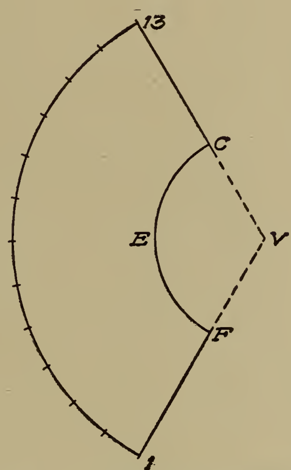

Fig. 147. Development of Cone

plane, the vertex remaining stationary until the same element is in contact again, the space rolled over will represent the development of the convex surface of the cone. Fig. 146 is a cone cut by a plane parallel to the base. In Fig. 147, let the vertex of the cone be placed at V, and one element of the cone coincide with $VF1$. The length of this element is taken from the elevation, Fig. 146, of either contour element. All of the elements of the cone are of the same length, so that when the cone is rolled, each point of the base as it touches the plane will be at the same distance from the vertex. From this it follows that in the development of the base,

the circumference will become the arc of a circle of radius equal to the length of an element, and of a length equal to the distance around the base. To find this length divide the circumference of the base in the plan into any number of equal parts, say twelve, and lay off twelve such spaces, 1 . . . . 13 along an arc drawn with radius equal to $V1$; join 1 and 13 with V, and the resulting sector is the development of the cone from vertex to base. In order to represent on the development the circle cut by the section plane DF, draw, from the vertex V as a center and with VF as a radius, the arc FC. The development of the frustum of the cone will be a portion of a circular ring. This of course does not include the development of the bases, which would be simply two circles the same sizes as shown in plan.

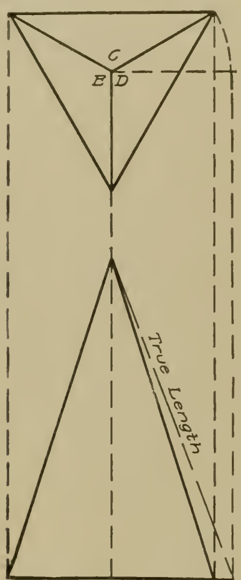

Fig. 148. Plan and Elevation of Triangular Pyramid

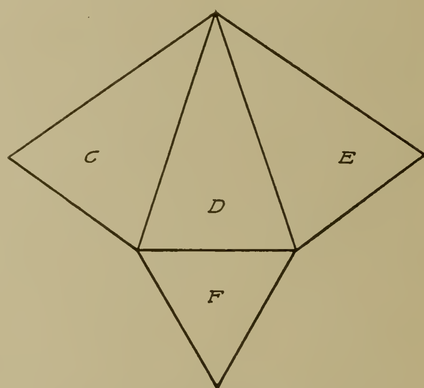

Fig. 149. Development of Triangular Pyramid

Regular Triangular Pyramid. Fig. 148 represents the plan and elevation of a regular triangular pyramid, and Fig. 149 its development. If face C is placed on the plane its true size will be shown in the development. The true length of the base of triangle C is shown in the plan. As the slanting edges, however, are not parallel to the vertical, their true length is not shown in elevation but must be obtained by the method given on page 88, as indicated in Fig. 148. The triangle may now be drawn in its full size at C in the development, and as the pyramid is regular, two other equal triangles,

D and *E*, may be drawn to represent the other sides. These, together with the base *F*, constitute the complete development.

Truncated Circular Cylinder. If a truncated circular cylinder is to be developed, or rolled upon a plane, the elements, being parallel, will appear as parallel lines, and the base line being perpendicular to the elements, will appear as a straight line of length equal to the circumference of the base. The base of the cylinder in Fig. 150 is divided into twelve equal parts, 1, 2, 3, etc., and commencing at point 1 on the development, these twelve equal spaces are laid off along the straight line, giving the total width.

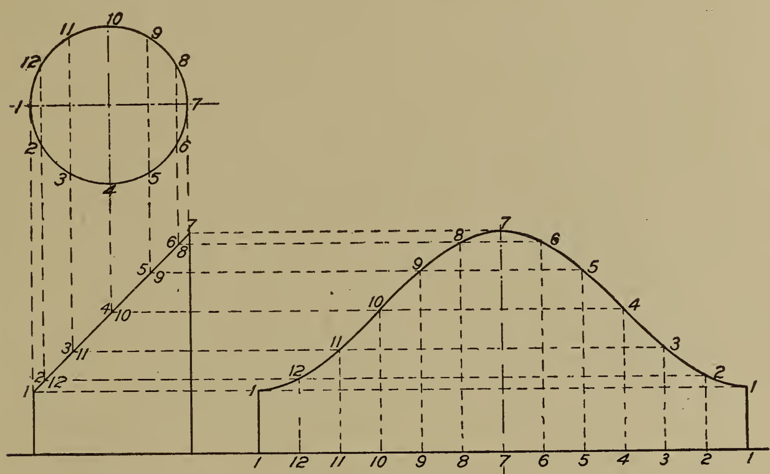

Fig. 150. Projections and Development of Truncated Cylinder

Draw in elevation the elements corresponding to the various divisions of the base, and note the points where they intersect the oblique plane. As the cylinder is rolled beginning at point 1, the successive elements, 1, 12, 11, etc., will appear at equal distances apart, and equal in length to the lengths of the same elements in elevation. Thus point number 10 on the development is found by projecting horizontally across from 10 in elevation. It will be seen that the curve formed is symmetrical, the half on the left of 7 being similar to that on the right. The development of any similar surface may be found in the same manner.

The principle of cylinder development is used in laying out elbow joints, pipe ends cut off obliquely, etc. In Fig. 151 is shown

plan and elevation of a three-piece elbow and collar, and developments of the four pieces. In order to construct the various parts making up the joint, it is necessary to know what shape and size must be marked out on the flat sheet metal so that when cut out and rolled up the three pieces will form cylinders with the ends fitting together as required. Knowing the kind of elbow desired, first draw the plan and elevation, and from these make the develop-

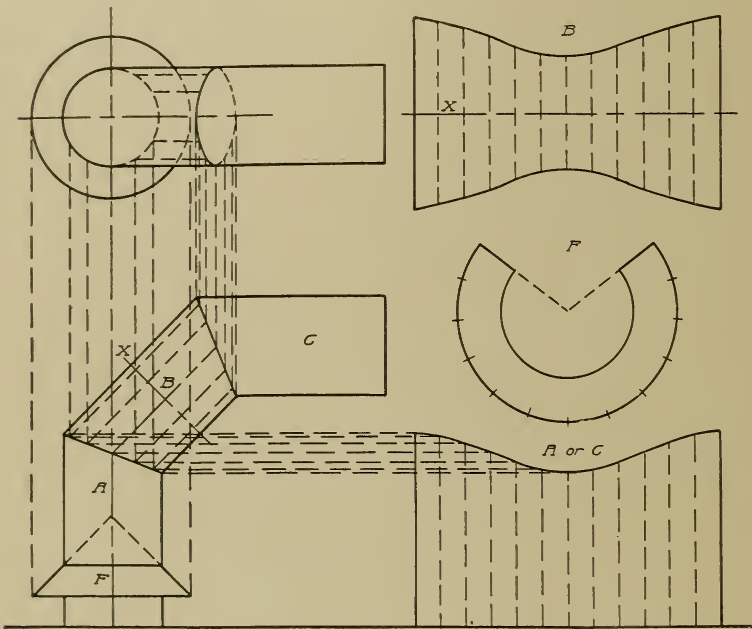

Fig. 151. Plan, Elevation, and Development of Three-Piece Elbow and Collar

ments. Let the lengths of the three pieces *A*, *B*, and *C* be the same on the upper outside contour of the elbow, the piece *B* at an angle of 45 degrees; the joint between *A* and *B* bisects the angle between the two lengths, and in the same way the joint between *B* and *C*. The lengths *A* and *C* will then be the same and one pattern will answer for both. The development of *A* is made exactly as just explained for Fig. 150, and this is also the development of *C*.

It should be borne in mind that in developing a cylinder the base must always be at right angles to the elements, and if the cylinder as given does not have such a base, it becomes necessary

to cut the cylinder by a plane perpendicular to the elements, and use the intersection as a base. This point must be clearly understood in order to proceed intelligently. A section at right angles to the elements is the only section which will unroll in a straight line, and is, therefore, the section from which the other sections must be developed. As *B*, Fig. 151, has neither end at right angles to its length, the plane *X* is drawn at the middle and perpendicular to the length. *B* has the same diameter as *C* and *A*, so the section cut by *X* will be a circle of the same diameter as the base of *A*, and is shown in the development at *X*.

The elements on *B* are drawn from the points where the elements on the elevation of *A* meet the joint between *A* and *B*, and are equally spaced as shown on the plan of *A*. Commencing with the left-hand element in *B*, the length of the upper element between *X* and the top corner of the elbow is laid off above *X*, giving the first point in the development of the end of *B* fitting with *C*. The lengths of the other elements in the elevation of *B* are measured in the same way and laid off from *X*. The development of the other end of the piece *B* is laid off below *X*, using the same distances, since *X* is half way between the ends. The development of the collar is simply the development of the frustum of a cone, which has already been explained, Fig. 147. The joint between *B* and *C* is shown in plan as an ellipse, the construction of which the student should be able to understand from a study of the figure.

ISOMETRIC PROJECTION

Isometric of a Cube. In orthographic projection an object has been represented by two or more projections; another system, called isometrical drawing, is often used to show in one view the three dimensions of an object, length (or height), breadth, and thickness. An isometrical drawing of an object, as a cube, is called for brevity the isometric of the cube.

To obtain a view which shows the three dimensions in such a way that measurements may be taken from them, draw the cube in the simple position shown at the left, Fig. 152, with two faces parallel to *V;* the diagonal from the front upper right-hand corner to the back lower left-hand corner is indicated by the dotted line. Swing the cube around until the diagonal is parallel with *V,* as shown in the

second position. Here the front face is at the right. In the third position the lower end of the diagonal has been raised so that it is parallel to *H*, becoming thus parallel to both planes. The plan is found by the principles of projection, from the elevation and the preceding plan. The front face is now the lower of the two faces shown in the elevation. From this position the cube is swung around, using the corner as a pivot, until the diagonal is perpendicular to *V* but still parallel to *H*. The plan remains the same, except as regards position; while the elevation, obtained by projecting across from the previous elevation, gives the isometrical projection of the cube. The front face is now at the left.

Distinction between Isometric Projection and Isometric Drawing. In the last position, as one diagonal is perpendicular to *V*, it follows

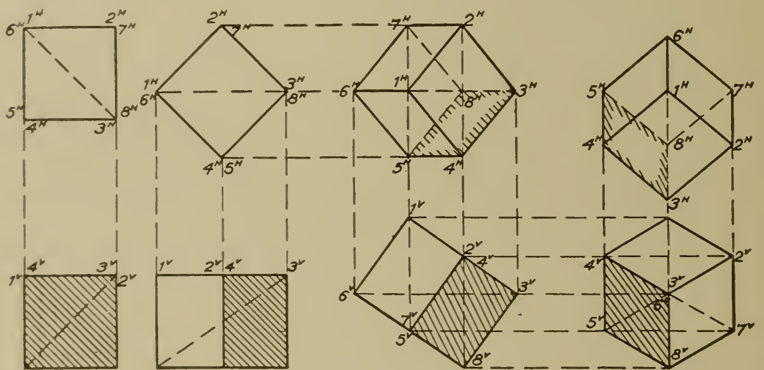

Fig. 152. Development of an Isometric of a Cube

that all the faces of the cube make equal angles with *V*, hence are projected on that plane as equal parallelograms. For the same reason all the edges of the cube are projected in elevation in equal lengths, but, being inclined to *V*, appear shorter than they actually are on the object. Since they are all equally foreshortened and since a drawing may be made at any scale, it is customary to make all the isometrical lines of a drawing full length. This will give the same proportions, and is much the simpler method. Herein lies the distinction between an isometric projection and an isometric drawing.

It will be noticed that the figure may be inscribed in a circle, and that the outline is a perfect hexagon. Hence the lines showing

breadth and length are 30-degree lines, while those showing height are vertical.

True Length of Lines. Fig. 153 shows the isometric of a cube 1 inch square. All of the edges are shown in their true length, hence

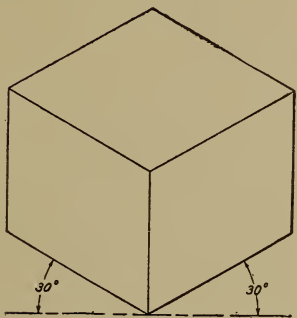

Fig. 153. Isometric of a Cube

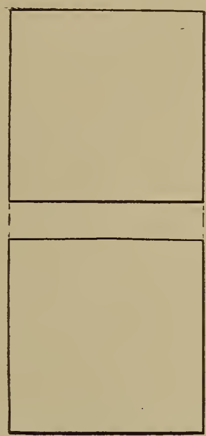

Fig. 154. Plan and Elevation of a Cube

all the surfaces appear of the same size. In the figure the edges of the base are inclined at 30 degrees with a T-square line, but this is not always the case. For rectangular objects, such as prisms, cubes, etc., the base edges are at 30 degrees only when the prism or cube is supposed to be in the simplest possible position. The cube in Fig. 153 is supposed to be in the position indicated by plan and elevation in Fig. 154, that is, standing on its base, with two faces parallel to the vertical plane.

If the isometric of the cube in the position shown in Fig. 155 were required, it could not be drawn with the base edges at 30 degrees; neither would these edges appear in their true lengths. It

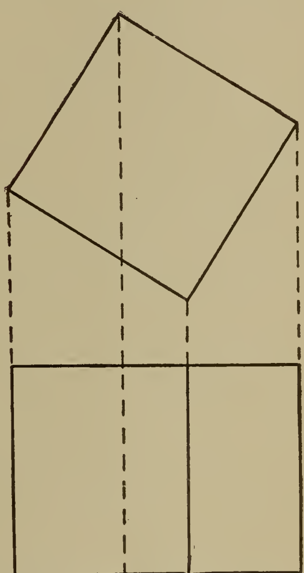

Fig. 155. Cube of Fig. 154 Rotated 30 Degrees with Vertical Plane

follows, then, that in isometrical drawing, true lengths appear only as 30-degree lines or as vertical lines. Edges or lines that in actual projection are either parallel to a T-square line or perpendicular to V, are drawn in isometric as 30-degree lines, full length; and those that are actually vertical are made vertical in isometric, also full length.

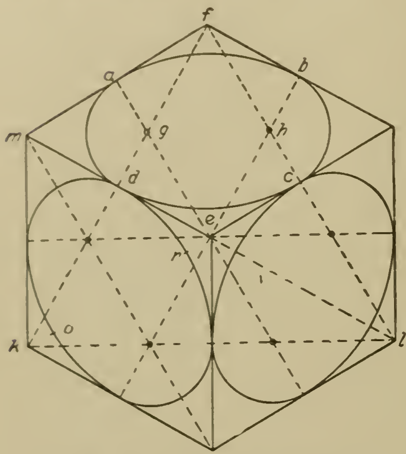

Fig. 156. Isometric of a Cube with Circles Inscribed on its Faces

Three Isometric Axes. In Fig. 152, lines such as the front vertical edges of the cube and the two base edges are called the *three isometric axes*. The isometric of objects in oblique positions, as in Fig. 155, can be constructed only by reference to their projections, by methods which will be explained in the section on "Oblique Projection", page 123.

Applications of Isometric Projections. In isometric drawing small rectangular objects are more satisfactorily represented than large curved ones. In woodwork, mortises and joints and various parts of framing are well shown in isometric. This system is used also to give a kind of bird's-eye view of mills or factories. It is also used in making sketches of small rectangular pieces of machinery, where it is desirable to give shape and dimensions in one view.

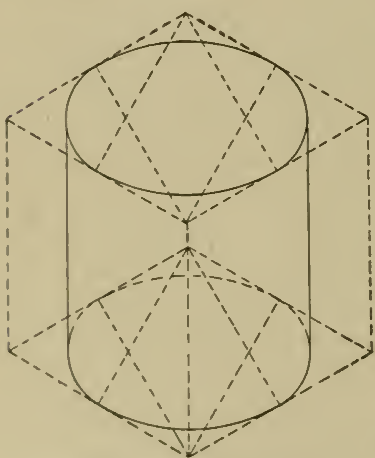
Fig. 157. Isometric of a Cylinder

Characteristics of Various Isometrics. *Cube with Inscribed Circles.* Fig. 156 shows a cube with circles inscribed in the top and two side faces. The isometric of a circle is an ellipse- the

exact construction of which would necessitate finding a number of points; for this reason an approximate construction by arcs of circles is often made. In the method, Fig. 156, four centers are used. Considering the upper face of the cube, lines are drawn from the obtuse angles f and e to the centers of the opposite sides. The intersections of these lines give points g and h, which serve as centers for the ends of the ellipse. With g as center and radius ga, the arc ad is drawn, and with f as center and radius fd, the arc

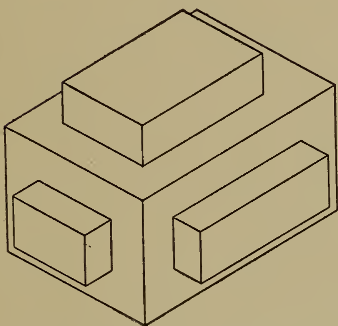

Fig. 158. Isometric of a Wooden Block

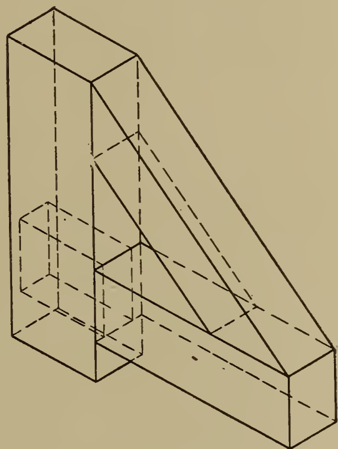

Fig. 159. Isometric of a Wooden Brace

dc is drawn; the ellipse is finished by using centers h and e. This construction is applied to all three faces.

Cylinder. Fig. 157 is the isometric of a cylinder standing on its base.

Blocks. Fig. 158 represents a block with smaller blocks projecting from three faces.

Framework. Fig. 159 shows a framework of three pieces, two at right angles and a slanting brace. The horizontal piece is mortised into the upright as indicated by the dotted lines.

House. In Fig. 160 the isometric outline of a house is represented, showing a dormer window and a partial hip roof; ab is a hip rafter, cd a valley. Let the pitch of the main roof be shown at B, and let m be the middle point of the top of the end wall of the house. Then, by measuring vertically up a distance ml equal to the vertical

height $a\,n$ shown at B, a point on the line of the ridge will be found at l. Line $l\,i$ is equal to $b\,h$, and $i\,h$ is then drawn. Let the pitch of the end roof be given at A. This shows that the peak of the roof, or the end a of the ridge, will be back from the end wall a distance equal to the base of the triangle at A. Hence, lay off from l this distance, giving point a, and join a with b and x.

The height $k\,e$ of the ridge of the dormer roof is known, and it must be found where this ridge will meet the main roof. The ridge must be a 30-degree line as it runs parallel to the end wall of the house and to the ground. Draw from e a line parallel to $b\,h$ to meet a vertical through h and f. This point is in the vertical plane of

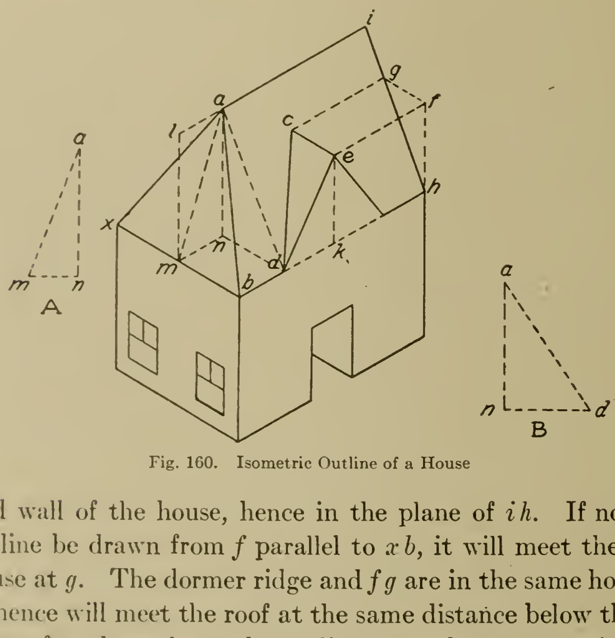

Fig. 160. Isometric Outline of a House

the end wall of the house, hence in the plane of $i\,h$. If now a 30-degree line be drawn from f parallel to $x\,b$, it will meet the roof of the house at g. The dormer ridge and $f\,g$ are in the same horizontal plane, hence will meet the roof at the same distance below the ridge $a\,i$. Therefore draw the 30-degree line $g\,c$, and connect c with d.

Box with Cover. In Fig. 161 a box is shown with the cover opened through 150 degrees. The right-hand edge of the bottom shows the width, the left-hand edge shows the length and the vertical edge shows the height. The short edges of the cover are not isometric lines, hence are not shown in their true lengths; neither is the angle through which the cover is opened represented in its actual size.

The corners of the cover must then be determined by co-ordinates from an end view of the box and cover. As the end of the cover

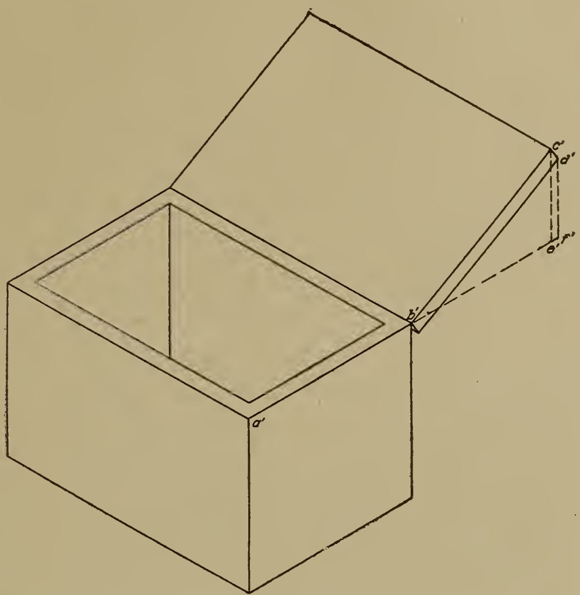

Fig. 161. Isometric of a Box and Cover

is in the same plane as the end of the box, the simple end view as shown in Fig. 162 will be sufficient. Extend the top of the box to the right, and from c and d let fall perpendiculars on ab produced, giving the points e and f. The point c may be located by means of the two distances or co-ordinates be and ec, and these distances will appear in their true lengths in the isometric view. Hence produce $a'b'$ to e' and f'; and from these points draw verticals $e'c'$ and $f'd'$; make $b'e'$ equal to be, $e'c'$ equal to ec; and similarly for d'. Draw the lower edge parallel to $c'd'$ and equal to it in length, and connect with b'.

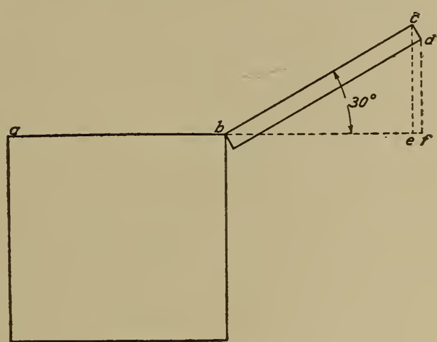

Fig. 162. End View of Box Shown in Fig. 161

It will be seen that in isometric drawing parallel lines always appear parallel. It is also true that lines divided proportionally maintain this same relation in isometric drawing.

Prism with Semicircular Top. Fig. 163 shows a block or prism with a semicircular top. Find the isometric of the square circumscribing the circle, then draw the curve by the approximate method. The centers for the back face are found by projecting the front centers back 30 degrees equal to the thickness of the prism, as shown at *a* and *b*.

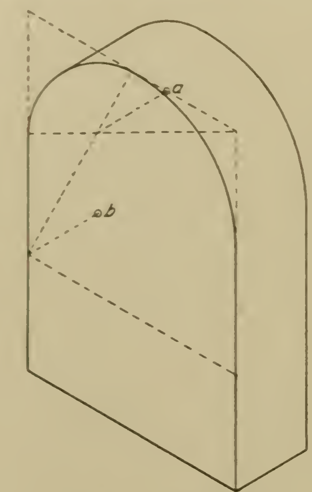

Fig. 163. Isometric of a Prism with Semicircular Top

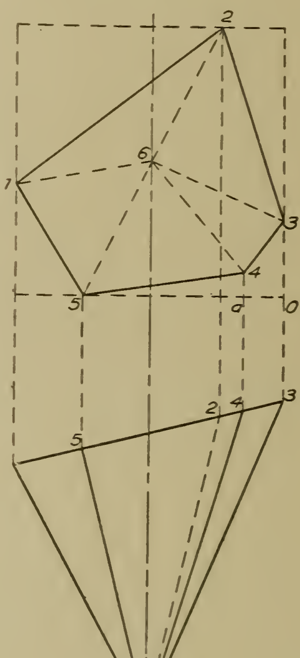

Fig. 164. Plan and Elevation of Oblique Pentagonal Pyramid

Fig. 165. Isometric of Fig. 164

Pyramid. The plan and elevation of an oblique pentagonal pyramid are shown in Fig. 164. It is evident that none of the edges

of the pyramid can be drawn in isometric as either vertical or 30-degree lines; hence a system of co-ordinates must be used as shown in Fig. 165. This problem illustrates the most general case; and to locate some of the points three co-ordinates must be used, two at 30 degrees and one vertical.

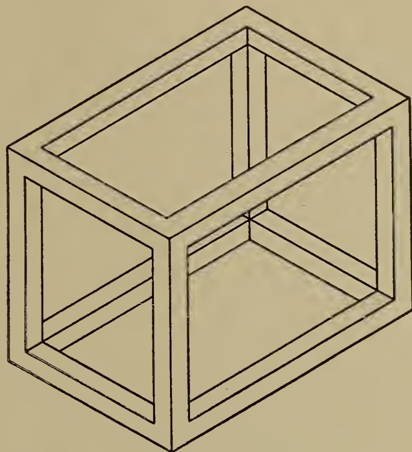

Fig.166. Isometric of a Skeleton of a Box

Circumscribe, about the plan of the pyramid, a rectangle which shall have its sides respectively parallel and perpendicular to a T-square line.

The isometric of this rectangle can be drawn at once with 30-degree lines, as shown in Fig. 165, o being the same point in both figures. The horizontal projection of point 3 is found in isometric at 3^h, at the same distance from o as in the plan. That is, *any distance which in plan is parallel to a side of the circumscribing rectangle, is shown in isometric in its true length and parallel to the corresponding side of the isometric rectangle.* If point 3 were on the horizontal plane its isometric would be 3^h, but the point is at the vertical height above H given in the elevation; hence, lay off above 3^h this vertical height, obtaining the actual isometric of the point. To locate point 4, draw $4a$ parallel to the side of the rectangle; then lay off oa and $a4^h$, giving what may be called the isometric plan of 4. The

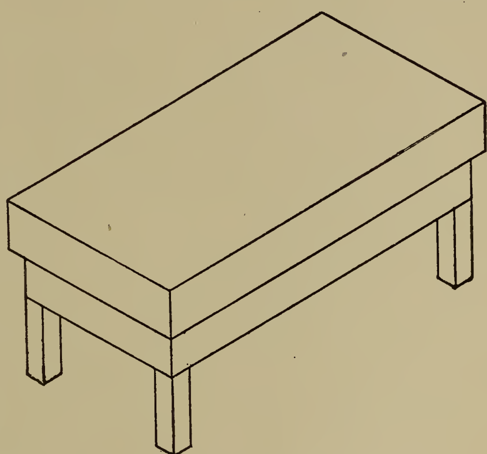

Fig. 167. Isometric of a Carpenter's Bench

vertical height taken from the elevation locates the isometric of the point.

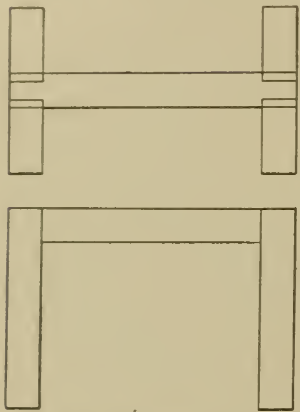

Fig. 168. Plan and Elevation of Sawhorse

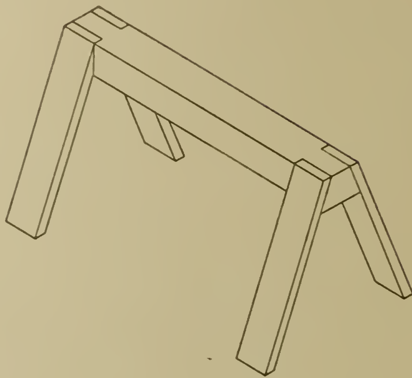

Fig. 169. Isometric of Fig. 168

In like manner all the corners of the pyramid, including the apex, are located. The rule is, *locate first in isometric the horizontal*

Fig. 170. End Elevation of Stairs

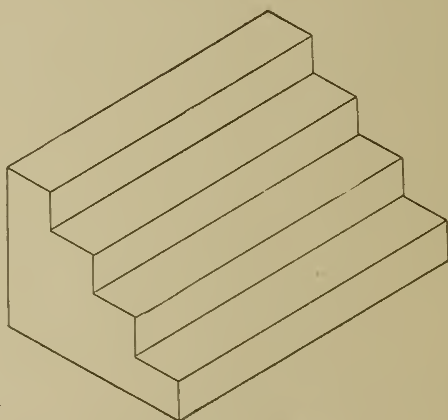

Fig. 171. Isometric of Stairs

projection of a point by one or two 30-degree co-ordinates; then vertically above this point, locate its height as taken from the elevation.

Figs. 166 to 173 give examples of the isometric of various objects.

Fig. 168 is the plan and elevation, and Fig. 169 the isometric, of a carpenter's sawhorse.

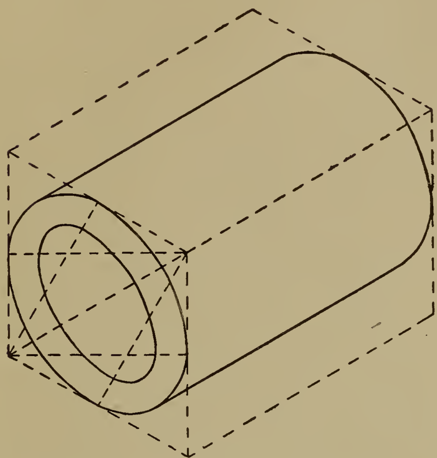

Fig. 172. Isometric of a Hollow Cylinder

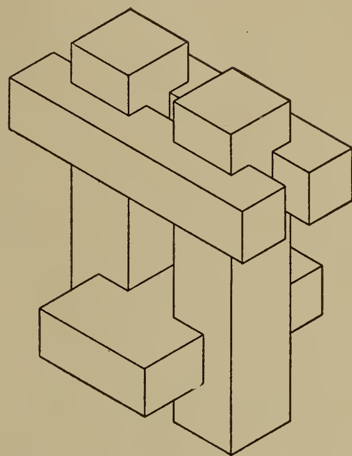

Fig. 173. Isometric of a Wooden Model

OBLIQUE PROJECTION

Comparison with Isometric Projection. In oblique projection, as in isometric, the end sought for is the same—a more or less complete representation, in one view, of any object. Oblique projection differs from isometric in that one face of the object is represented as if parallel to the vertical plane of projection, the others inclined to it. Another point of difference is that oblique projection cannot be deduced from orthographic projection, as is isometric.

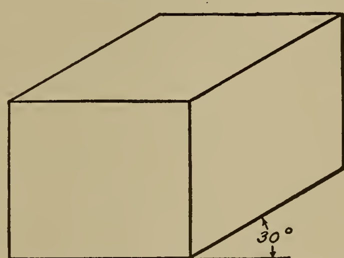

Fig. 174. Oblique View of Cube at 30 Degrees

Characteristics of Method. In oblique projection all lines in the front face are shown in their true lengths and in their true relation to one another, and lines which are perpendicular to this front face are shown in their true lengths at any angle that may be desired for any particular case. Lines not in the plane of the front face nor perpendicular to it must be determined by co-ordinates, as in isometric. It will be seen at once that this system

possesses some advantages over the isometric, as, for instance, in the representation of circles, as any circle or curve in the front face is actually drawn as such. Fig. 174, Fig. 175, and Fig. 176 show a cube in oblique projection with the 30-degree, 45-degree, and 60-degree slant, respectively. Fig. 177 shows a hollow cylinder in oblique projection. Figs 178, 179, 180, 182 are other examples of oblique projections. Fig. 180 is a crank arm.

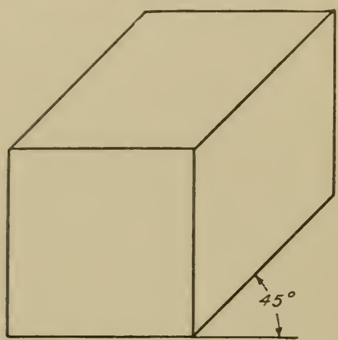

Fig. 175. Oblique View of Cube at 45 Degrees

The method of using co-ordinates for lines of which the true lengths are not shown, is illustrated by Figs 181 and 182. Fig. 182 represents the oblique projection of the two joists shown in plan and elevation in Fig. 181. The dotted lines in the elevation, Fig. 181, show the heights of the corners above the horizontal stick. The feet of these perpendiculars give the horizontal distances of the top corners from the end of the horizontal piece.

In Fig. 182 lay off from the upper right-hand corner of the front end a distance equal to the distance between the front edge of the inclined piece and the front edge of the bottom piece, Fig. 181. From this point draw a dotted line parallel to the length. The horizontal distances from the upper left corner to the dotted perpendicular are then marked off on this line. From these points verticals

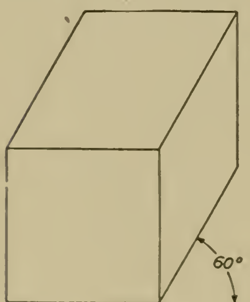

Fig. 176. Oblique View of Cube at 60 Degrees

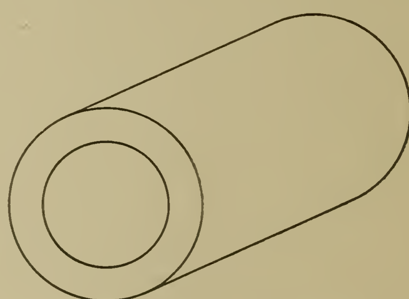

Fig. 177. Oblique View of Hollow Cylinder

are drawn, and made equal in length to the dotted perpendiculars of Fig. 181, thus locating two corners of the end.

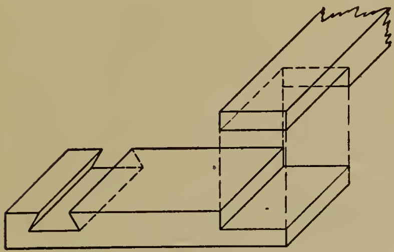

Fig. 178. Oblique View of a Miter Joint

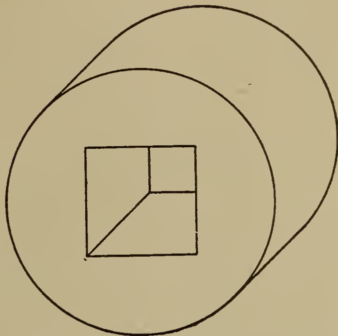

Fig. 179. Oblique View of Cylinder

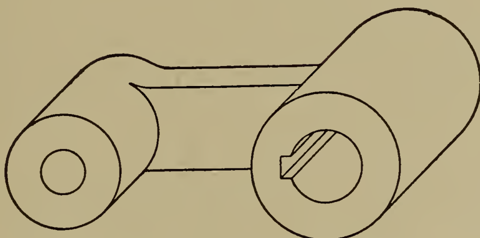

Fig. 180. Oblique View of Crank Shaft

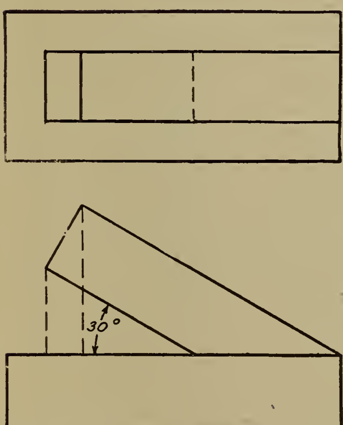

Fig. 181. Plan and Elevation of Wooden Brace

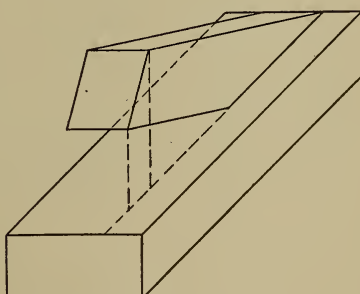

Fig. 182. Oblique View of Wooden Brace

LINE SHADING

Object of Line Shading. In finely finished drawings it is frequently desirable to make the various parts more readily seen by showing the graduations of light and shade on the curved surfaces. This is especially true of such surfaces as cylinders, cones, and spheres. The effect is obtained by drawing a series of parallel or converging lines on the surface at varying distances from one another. Sometimes draftsmen, themselves, vary the width of the lines. These lines are farther apart on the lighter portion of the surface, and closer together and heavier on the darker part.

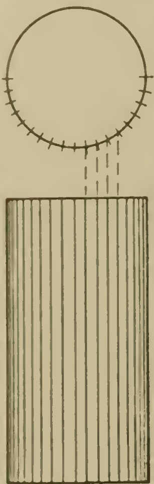

Fig. 183. Plan and Shaded Elevation of Cylinder

Fig. 183 shows a cylinder with elements drawn on the surface equally spaced on the plan. On account of the curvature of the surface, however, the elements are not equally spaced on the elevation, in order to give the effect of the graduations of light on the curved surface. The result is that in drawing the elevation of the cylinder, the distances between the elements are made gradually less from the center toward each side, thus giving a correct representation of the convexity of the cylinder. This effect is intensified by making the

Fig. 184. Shaded Vertical Cylinder

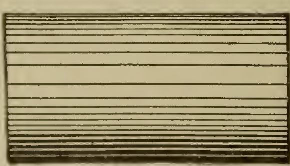

Fig. 185. Shaded Horizontal Cylinder

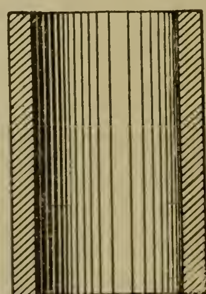

Fig. 186. Shaded Section of Hollow Cylinder

outside elements heavier as well as closer together, as shown in Figs. 184 to 190. Concavity is shown in the same manner, the

heavy shading always appearing on the left to indicate the deeper shadow, Figs. 186 and 188.

Fig. 184 is a cylinder showing the heaviest shade at the right, a method often used. Considerable practice is necessary to obtain good results; but in this, as in other portions of mechanical drawing, repetition is unavoidable. Fig. 185 represents a cylinder in a hori-

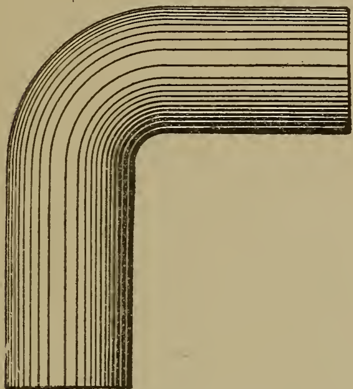

Fig. 187. Shaded Elbow Joint

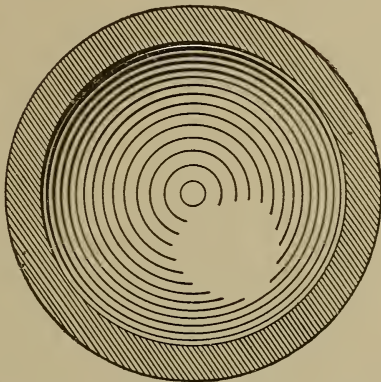

Fig. 188. Shaded Section of Hollow Sphere

zontal position, and Fig. 186 represents a section of a hollow vertical cylinder. Figs. 187 to 190 give other examples of familiar objects.

Fig. 189. Shaded Sphere

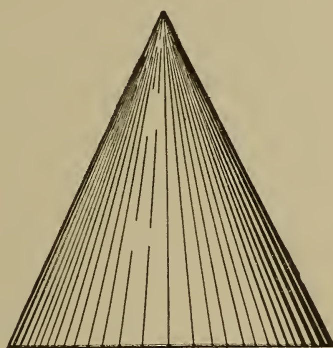

Fig. 190. Shaded Cone

In the elevation of the cone shown in Fig. 190 the shade lines should diminish in weight as they approach the apex. Unless this is done it will be difficult to avoid the formation of a blot at that point.

LETTERING

Types of Lettering. In the early part of this course, the inclined Gothic letter was described, and the alphabet given. The Roman, Gothic, and block letters are perhaps the most used for titles. These letters, being of comparatively large size, are generally made mechanically; that is, drawing instruments are used in their construction. In order that the letters may appear of the same height, some of them, owing to their shape, must be made a little higher than the others. This is the case with the letters curved at the top and bottom, such as C, O, S, etc., as shown somewhat exaggerated in Fig. 191. Also, the letter A should extend a little above, and V a little below, the guide lines, because if made of the same height as the others they will appear shorter. This is true of all capitals, whether of Roman, Gothic, or other alphabets. In the block letter, however, they are frequently all of the same size.

Size of Letters. There is no absolute size or proportion of letters, as the dimensions are regulated by the amount of space in which the letters are to be placed, the size of the drawing, the effect desired, etc. In some cases letters are made so that the height is greater than the width, and sometimes the reverse; sometimes the height and width are the same. This last proportion is the most common. Certain relations of width, however, should be observed. Thus, in whatever style of alphabet used, the W should be the widest letter; J the narrowest, M and T the next widest to W, then A and B. The other letters are of about the same width.

Vertical Gothic. In the vertical Gothic alphabet, the average height is that of B, D, E, F, etc., and the additional height of the curved letters and of the A and V is very slight. The horizontal cross lines of such letters as E, F, H, etc., are slightly above the center; those of A, G, and P slightly below.

Inclined Gothic. For the inclined letters, Fig. 192, 60 degrees is a convenient angle, although they may be at any other angle suited to the convenience or fancy of the draftsman. Many draftsmen use an angle of about 70 degrees.

Roman. The letters of the Roman alphabet, whether vertical, Fig. 193, or inclined, Fig. 194, are quite ornamental in effect if well made, the inclined Roman being a particularly attractive letter.

Fig. 191. Vertical Gothic Letters and Figures

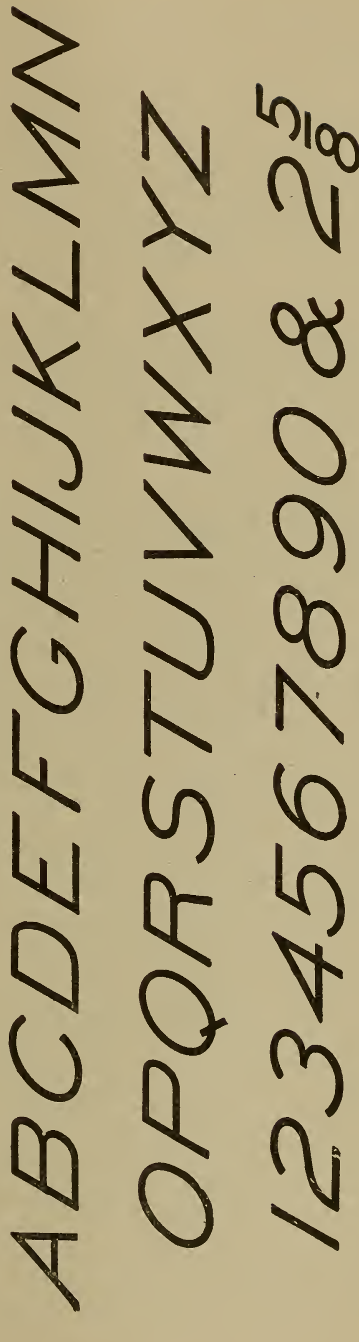

Fig. 192. Inclined Gothic Letters and Figures

Fig. 193. Vertical Roman Letters and Figures

Fig. 194. Inclined Roman Letters and Figures

although rather difficult to make. The block letter, Fig. 195, is made on the same general plan as the Gothic, but much heavier. Small squares are taken as the unit of measurement, as shown. The use of this letter is not advocated for general work, although

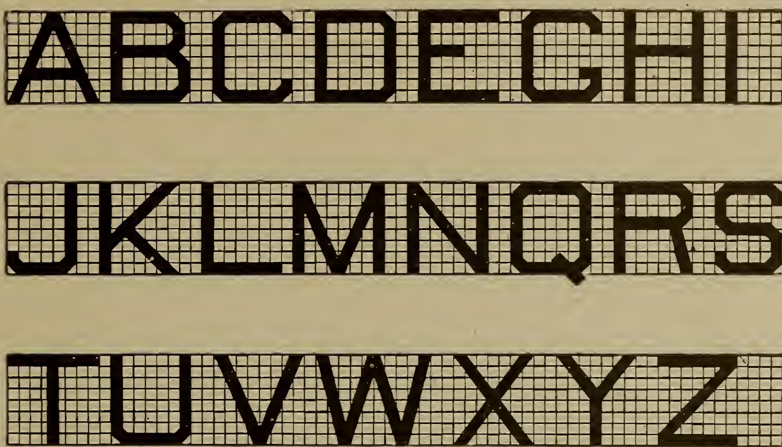

Fig. 195. Block Letters

if made merely in outline the effect is pleasing. The styles of numbers, corresponding with the alphabets of capitals given here, are also inserted. When a fraction, such as $2\frac{5}{8}$ is to be made, the proportion should be about as shown. For small letters, usually

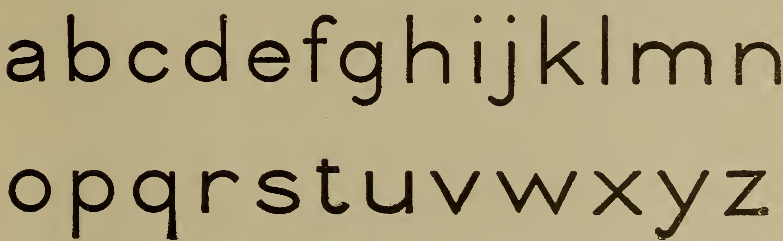

Fig. 196. Vertical Gothic Lower-Case Letters

called lower-case letters, the height may be made about two-thirds that of the capitals. This proportion, however, varies in special cases.

Lower-Case Letters. The principal lower-case letters in general use among draftsmen are shown in Figs. 196, 197, 198, and 199.

The Gothic letters shown in Figs 196 and 197 are much easier to make than the Roman letters in Figs. 198 and 199. These letters,

abcdefghijklmn
opqrstuvwxyz

Fig. 197. Inclined Gothic Lower-Case Letters

however, do not give as finished an appearance as the Roman. As has already been stated in Mechanical Drawing, Part I, the inclined letter is easier to make because slight errors are not so apparent.

abcdefghijklmn
opqrstuvwxyz

Fig. 198. Vertical Roman Lower-Case Letters

Spacing. One of the most important points to be remembered in lettering is the spacing. If the letters are finely executed but

abcdefghijklmn

opqrstuvwxyz

Fig. 199. Inclined Roman Lower-Case Letters

poorly spaced, the effect is not good. To space letters correctly and rapidly requires considerable experience; and rules are of little

TECHNICALITY

Fig. 200. Sample of Letter Spacing

value on account of the many combinations in which letters are found. A few directions, however, may be found helpful. For

instance, take the word TECHNICALITY, Fig. 200. If all the spaces were made equal, the space between the L and the I would appear to be too great, and the same would apply to the space between the I and the T. The space between the H and the N and that between the N and the I would be insufficient. Usually, when the vertical side of one letter is followed by the vertical side of another, as in H E, H B, I R, etc., the maximum space should be allowed. Where T and A come together the least space is given, for in this case the top of the T frequently extends over the bottom of the A. In general, the spacing should be such that a uniform appearance is obtained. For the distances between words in a sentence, a space of about $1\frac{1}{2}$ the width of the average letter may be used. The space, however, depends largely upon the desired effect.

Penciling before Inking. For large titles, such as those placed on charts, maps, and some large working drawings, the letters should be penciled before inking. If the height is made equal to the width, considerable time and labor will be saved in laying out the work. This is especially true with such Gothic letters as O, Q, C, etc., as these letters may then be made with compasses. If the letters are of sufficient size, the outlines may be drawn with the ruling pen or compasses, and the spaces between filled in with a fine brush.

Titles for Working Drawings. The titles for working drawings are generally placed in the lower right-hand corner. Usually a draftsman has his choice of letters, mainly because after he has become used to making one style he can do it rapidly and accurately. However, in some drafting rooms the head draftsman decides what lettering should be used. In making these titles, the different alphabets are selected to give the best results without spending too much time. In most work the letters are made in straight lines, although frequently a portion of the title is found lettered on an arc of a circle.

In Fig. 201 is shown a title having the words CONNECTING ROD lettered on an arc of a circle. To do this work requires considerable patience and practice. First, draw the vertical center line as shown at C in Fig. 201, then, draw horizontal lines for the horizontal letters. The radii of the arcs depend upon the general

arrangement of the entire title, and this is a matter of taste. The difference between the arcs should equal the height of the letters. After the arc is drawn, the letters should be sketched in pencil to find their approximate positions. After this is done, draw radial lines from the center of the letters to the center of the arcs. These

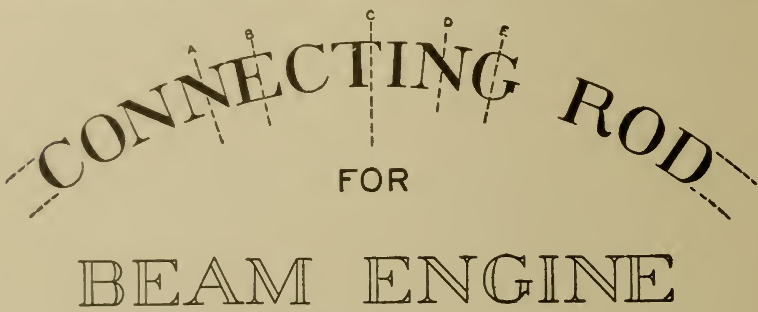

Fig. 201. Sample Title

lines will be the centers of the letters, as shown at *A, B, D,* and *E.* The vertical lines of the letters should not radiate from the center of the arc, but should be parallel to the center lines already drawn; otherwise the letters will appear distorted. Thus, in the letter *N*

SAFETY STOP VALVE

Fig. 202. Sample Title

the two verticals are parallel to the line *A*. The same applies to the other letters in the alphabet. In making the curved letters such as O and C, the centers of the arcs will fall upon these center lines; and if the compasses are used, the lettering is a comparatively simple matter. In Fig. 202 is shown another title in which all the letters are in horizontal lines.

PLATES

Plates IX to XV, inclusive, are to be drawn by the student for practice in applying the principles of orthographic projection, intersections and developments, isometric and oblique projection, and for practice in lettering. These plates are to be made 11 inches by 15 inches outside, with a margin of $\frac{1}{2}$ inch, making the clear space for the drawing 10 inches by 14 inches. All the plates are to be inked.

PLATE IX

After laying out the border line on the plate, draw a ground line horizontally across the upper part of the plate, 3 inches below the upper border line. On this ground line six figures, spaced as regularly as possible, are to be drawn, as follows:

1. Draw the projections of a line $1\frac{1}{2}$ inches long which is parallel to both planes, 1 inch above the horizontal, and $\frac{3}{4}$ inch from the vertical.

2. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. Lower end of line is $\frac{1}{2}$ inch above H.

3. Draw the projections of two intersecting lines: one 2 inches long to be parallel to both planes, 1 inch above H, and $\frac{3}{4}$ inch from the vertical; and the other to be oblique to both planes and of any desired length.

NOTE. The idea for drawing the three figures referred to in 1, 2, and 3 can be obtained from Figs. 104 and 105 in this textbook.

4. Find the true length of a line whose vertical projection is $1\frac{1}{4}$ inches long, the left end on the ground line and inclined at 30 degrees. The horizontal projection has the left end $\frac{1}{2}$ inch from V, and the right $1\frac{1}{2}$ inches from V.

5. Find the true length of a line whose horizontal projection is 1 inch long, whose right end is $\frac{1}{2}$ inch above the ground line, and inclined at 60 degrees. The vertical projection has the right end $\frac{1}{2}$ inch below the ground line and the left 1 inch.

6. Find the true length of a line whose projections are perpendicular to the ground line. The horizontal projection is 2 inches long, the bottom end being $\frac{1}{2}$ inch above the ground line. The vertical projection is 1 inch long, the top end being $\frac{1}{2}$ inch below the ground line.

NOTE. The idea for drawing the figures referred to in 4, 5, and 6 can be obtained from Figs. 120 and 121 in this textbook.

In the lower half of the plate, four more figures are to be drawn, also spaced as regularly as possible, so that the finished plate will be well balanced:

7. Draw the plan and elevation of a round bolt with a square head. The head is to be uppermost in the elevation. The bolt

is to be 2 inches long and $\frac{1}{2}$ inch in diameter. The head is to be $\frac{3}{4}$ inch square, $\frac{1}{4}$ inch thick, and have one face parallel to V.

8. Draw the plan and elevation of a round bolt having the same dimensions as in 7, but with a hexagonal head; the head to be uppermost in the elevation, and to be $\frac{3}{4}$ inch in width between faces $\frac{1}{4}$ inch thick, and to have one face parallel to V.

9. Draw the plan and elevation of a cylinder, perpendicular to H, 2 inches high and 2 inches in diameter, with a hole 1 inch in diameter passing vertically completely through it.

10. Draw the plan, elevation, and end view of a rectangular block 6 inches long, 2 inches wide, and 1 inch thick. One of the 2 inch by 6 inch sides is to be parallel to H. The right end is turned down to a cylindrical form 1 inch in length and 1 inch in diameter.

In all the work of this plate, construction lines should be fine dotted lines and should be inked in.

PLATE X

The figures on the reproduced Plate X on the opposite page give the outline of the work that is to be completed by the student. The dimensions given on this plate are to be used in working out the problem, but are not to appear on the finished plate. The first figure shown represents a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. In drawing these figures, the student must put in all construction lines in order to show how each view is obtained.

After completing the construction of the views as shown, the projection of four holes, $\frac{1}{2}$ inch in diameter each, are to be drawn. One hole passes through the center of each end, and one hole through the center of each side. All these small holes pass completely through to the large hole in the center of the block. Next, put two square projecting pieces on the front face of the block, on the center line, $\frac{1}{2}$ inch from each end. These projecting pieces are to be $\frac{1}{2}$ inch square and $\frac{1}{4}$ inch deep.

The projections of the four small holes and two projecting pieces are to be drawn in all views in the conventional manner, and the necessary construction lines for this work are to be left on the plate and inked in.

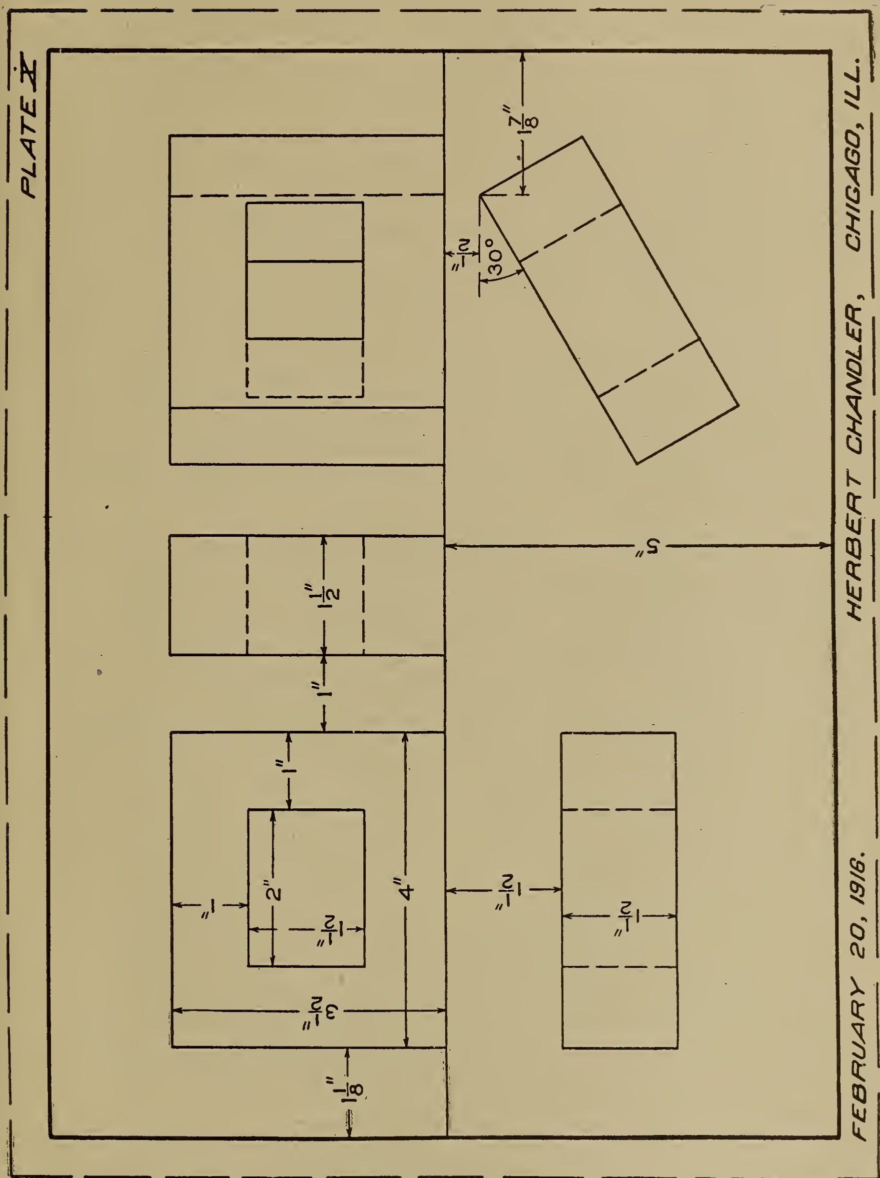
PLATE X
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 20, 1918.
1 7/8"
1/2"
30°
5"
1 1/2"
1"
1"
2"
4"
1"
1/2"
1/2"
1/2"
3 1/2"
1 1/8"

PLATE XI

At the left of this plate draw the plan, front and side views of the monument shown in elevation on reproduced Plate XI on the opposite page. The total height of the monument is 6 inches. All four sides are alike except that the width of the base is 2 inches and the depth $1\frac{1}{2}$ inches, and the width of the body of the monument is $1\frac{1}{2}$ inches and the depth 1 inch. The height of the base is $\frac{1}{2}$ inch, of body 3 inches, and the faces just above the base have a slope of 60 degrees with the horizontal. The width of the ridge at the extreme top of the monument is 1 inch.

The figures for the right side of the plate represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical. The height of the pyramid is $2\frac{1}{2}$ inches, and the diameter of the circle circumscribed about the base $2\frac{1}{2}$ inches. The center of the circle is 6 inches from the left margin and $2\frac{1}{2}$ inches below the upper border line. Spaces between figures to be $\frac{1}{2}$ inch.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis, through an angle of 15 degrees. The axis of the pyramid, shown dot and dash, is therefore at 75 degrees. The method of obtaining 75 degrees and 15 degrees with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position; hence the vertical projection will be the same shape and size as before. All points of the pyramid remain the same distance from V. The points on the plan are found on T-square lines through the corners of the first plan and directly above the points in elevation. In the third position the pyramid has been swung around, about a vertical line through the apex as axis, through 30 degrees. The angle with the horizontal plane remains the same; consequently the plan is the same size and shape as in the second position, but at a different angle. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation.

PLATE XII

DEVELOPMENTS

On this plate draw the developments of a truncated octagonal prism, and of a truncated pyramid having a square base. The

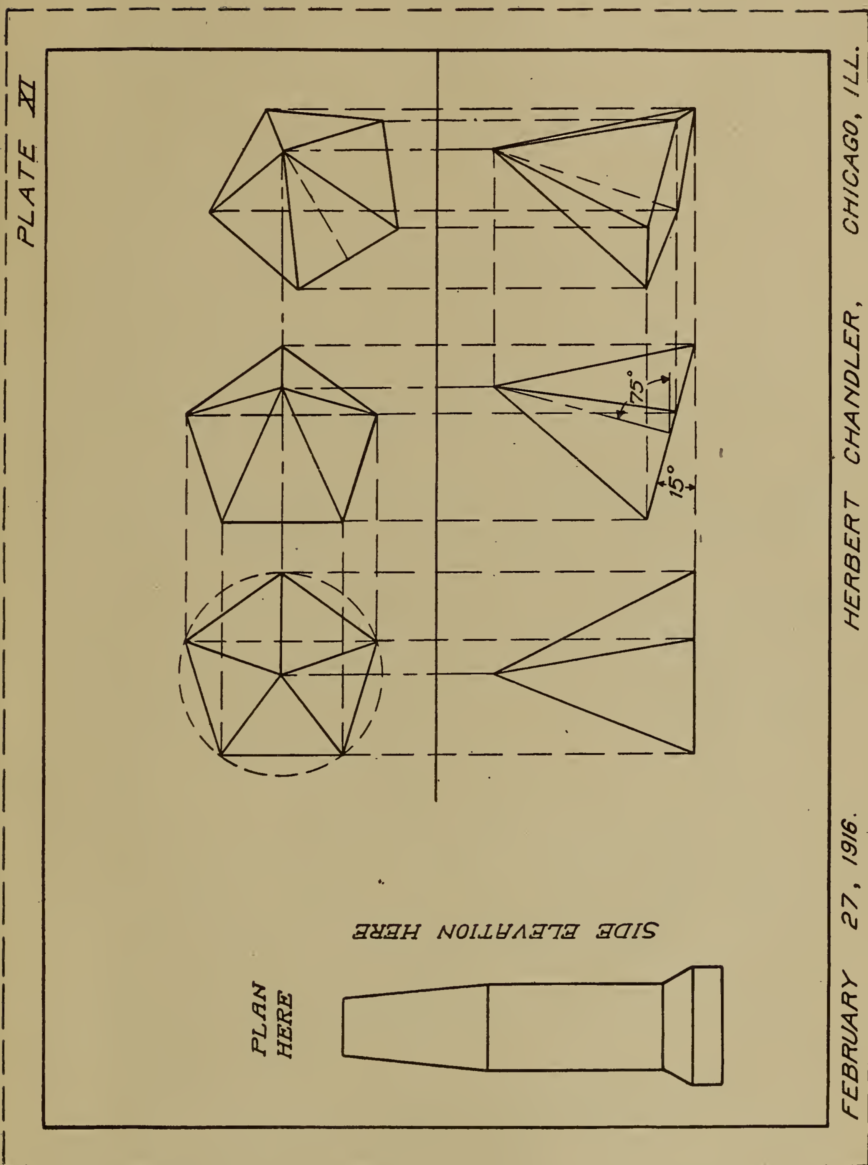
PLATE XI
75°
15°
SIDE ELEVATION HERE
PLAN HERE
FEBRUARY 27, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

arrangement on the plate is left to the student; but it is suggested that the truncated prism and its development be placed at the left,

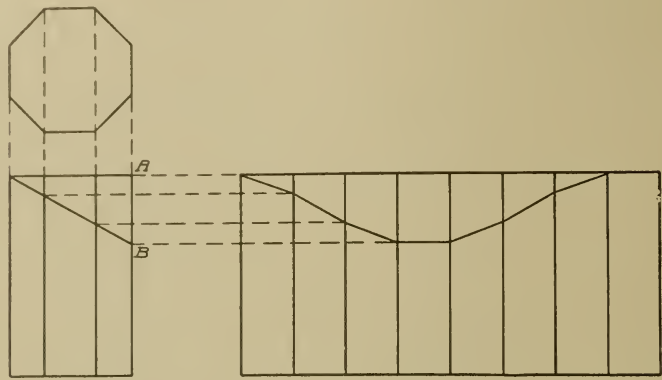

Fig. 203. Plan, Elevation, and Development of an Octagonal Prism

and that the development of the truncated pyramid be placed under the development of the prism; the truncated pyramid may be placed at the right.

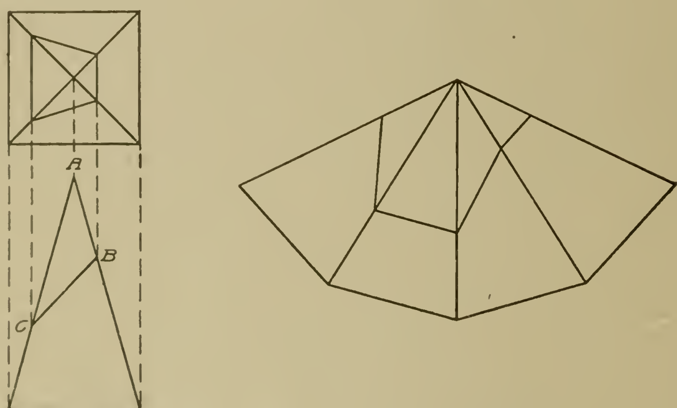

Fig. 204. Plan, Elevation, and Development of a Square Pyramid and Cutting Plane

The prism and its development are shown in Fig. 203. The prism is 3 inches high, and the base is inscribed in a circle $2\frac{1}{8}$ inches in diameter. The plane forming the truncated prism is passed as indicated, the distance AB being 1 inch. Ink a sufficient number of construction lines to show clearly the method of finding the development.

The pyramid and its development are shown in Fig. 204. Each side of the square base is 2 inches, and the altitude is $3\frac{1}{2}$ inches. The plane forming the truncated pyramid is passed in such a position that AB equals $1\frac{3}{8}$ inches, and AC equals $2\frac{1}{2}$ inches. In this figure the development may be drawn in any convenient position, but in the case of the prism it is better to draw the development as shown. Indicate clearly the construction by inking the construction lines.

PLATE XIII

ISOMETRIC AND OBLIQUE PROJECTION

In the upper left quarter of this plate draw the isometric projection of the block which is shown on reproduced Plate X, page 137, taking the dimensions from your finished Plate X. The idea for this problem can be obtained by referring to Fig. 158 in this textbook.

In the upper right quarter of this plate draw the isometric projections of the two round bolts described in 7 and 8 of Plate IX, taking dimensions from your finished Plate IX.

In the lower half of this plate draw, at 45 degrees, the oblique projections of the cylinder and the rectangular block, described in 9 and 10 of Plate IX, taking dimensions from your finished Plate IX. The idea for this can be obtained by referring to Figs. 175 and 179 in this textbook.

PLATE XIV

FREE-HAND LETTERING

On account of the importance of free-hand lettering, the student should practice it at every opportunity. For additional practice, and to show the improvement made since completing Part I, lay out Plate XIV in the same manner as Plate I, and letter all four rectangles. Use the same letters and words as in the lower right-hand rectangle of Plate I.

PLATE XV

LETTERING

First lay out Plate XV in the same manner as previous plates. After drawing the vertical center line, draw light pencil lines as

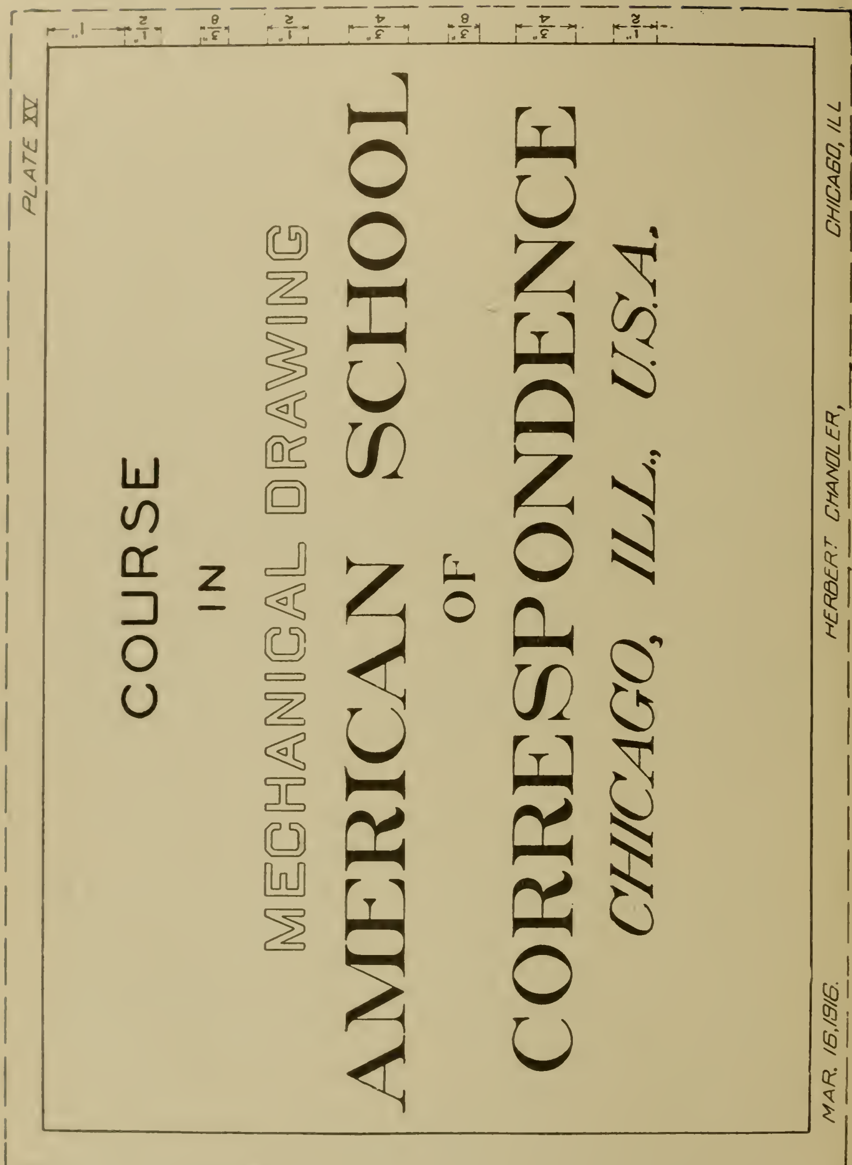
PLATE XV
COURSE
IN
MECHANICAL DRAWING
AMERICAN SCHOOL
OF
CORRESPONDENCE
CHICAGO, ILL., U.S.A.
MAR. 16, 1916.
HERBERT CHANDLER,
CHICAGO, ILL.

guide lines for the letters. The height of each line of letters is shown on the reproduced plate. The distance between the letters should be $\frac{1}{2}$ inch in every case. The spacing of the letters is left to the student. He may facilitate his work by lettering the words on a separate piece of paper, and finding the center by measurement or by doubling the paper into two equal parts. The styles of letters shown on the reproduced plate should be used.

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INDEX

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